Study Guide Lecture Exam 3 F2020

PROTOSTOMES: Ecdysozoa

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Phylum Nematoda – roundworms

- **Non-cellular cuticle** around body that must be shed for growth (**Ecdysozoan**)
- Billions of roundworms in **topsoil**
- Many nematodes are **parasites** or plants and animals.
- **Longitudinal muscles only**, so they can only move side to side.
- Intestinal wall one cell thick.
- Most are **dioecious** (separate sexes)
- **Internal fertilization**, males have copulatory spicule.
- **Eutely**
- **Examples:**
  - ***Ascaris*** responsible for infections in humans and pigs.
  - **Hookworms** in southern US, transfer from soil to blood through skin
  - ***Trichinella*** causes trichinosis
    - All are found in humans, go from blood to lungs, coughed up, swallowed, mature in intestine.
  - **Pinworms**, most common nematode parasite in US.
    - Females migrate out of anus to lay eggs. Itchy, kids scratch and re-ingest eggs.
  - **Filarial worms**, cause **heartworm** in dogs and cats, **elephantitis** in humans, **river blindness**
  - ***C. elegans***
- **Plant nematodes**
  - ***M. incognita* life cycle**
  - Chalcones – What are they? What benefits? Toxicity?

Phylum Arthropoda: (Know which organisms are related to which and the characteristics that place them in their group.)
Subphylum Trilobita, Subphylum Chelicerata, Subphylum Crustacea, Subphylum Myriapoda, Subphylum Hexapoda

Over ¾ of all known species in this phylum.
Segmented true coelomates
Exoskeleton (cuticle) is secreted, and jointed
Ecdysis (molting) must occur for growth.
Body size limited by weight of exoskeleton
Tracheal tubes in sides of abdomen deliver oxygen
Aquatic forms have gills
Some have **multiple eyes** or **compound eyes** or both.

(Subphylum Trilobita)

Extinct. Looks like large pill bug or roly-poly.

Subphylum Chelicerata (spiders, ticks, mites, horseshoe crabs)

Have **Chelicera** (piercing mouthparts or fangs), **pedipalps** (Mini legs for food grasping, with pincers in horseshoe crabs) and 4 pairs of walking legs.
No antennae.
Suck up liquid food from prey.

Class Xiphosura: Horseshoe crabs: look same as ancestors from Triassic
Cephalothorax (fused head and thorax) with 5 pairs legs and **abdomen** with modified legs.
Live in shallow water.
External fertilization.

Class Arachnida are spiders, scorpions, ticks, mites

Order Aranea: Spiders:
Cephalothorax (has all appendages), and **abdomen**.
Venom glands attached to fangs (**chelicerae**)
Spinning glands (**spinnerets**) on abdomen, liquid protein secreted that hardens in contact with air. Silk used for webs, lining burrows, egg sacs, wrapping prey.
Male **pedipalps** (what do pedipalps look like?) used as sensory stuctures, also for **sperm transfer.**
Spiders have **book lungs** for oxygen uptake.
Spiders have **8 eyes** with lens, rods, retina, but poor vision. Have sensory hairs on body.

Order Scorpiones: Scorpions: have **stinger with venom** at end of abdomen.
Nocturnal hunters of insects and spiders.

Subclass Acari: Ticks and mites: **complete fusion** of cephalothorax and abdomen
Chelicera pierce, grip or tear food.
4 pairs of legs.
House dust mites, hair follicle mites, spider mites on plants
Ticks carry Lyme disease, Rocky Mountain Spotted Fever

(Subphylum Myriapoda) (centipedes and millipedes)

Centipedes: 1 pair of legs per segment.
Eat earthworms, cockroaches, insects
Most small and harmless to humans, except tropical ones.
Venomous claw like a fang near mouth.

Millipedes: 2 pairs of legs per segment.
Eat decaying plants tissue (some eat live plants)
Coil for defense.
Secrete **toxic/repellant fluids** so they won't be eaten.

(Subphylum Crustacea) (crabs, lobsters, shrimp, crayfish, barnacles and others)

2 pairs of antennae, **mandibles** in mouth for chewing, and accessory legs **(maxillae)** for feeding.

Practically one pair of appendages per segment throughout body.

What do they do with all those legs?

Biramous appendages (2 parts to each) Walking legs have **gills attached**.

3 body parts: Head, thorax and abdomen, and head and thorax may be fused (**cephalothorax**); 2 pairs of antennae

Secreted cuticle (exoskeleton) made of chitin, protein and calcium carbonate.

Open circulatory system

Green gland (bladder) at ventral part of head for excreting liquid waste.

Crayfish have separate sexes

Eggs stay in a body chamber or attached to appendages.

Epidermis secretes shell (not a mantle).

Shedding or ecdysis for growth to occur.

Gastric mill (teeth in stomach) in crayfish.

Barnacles are sessile, legs act as filters for feeding, body "upside-down". Barnacles have 2 shells – are they related to clams and oysters? (NO)

Are **Isopods** (pillbugs) really bugs? (NO) Are they insects? (NO)

(Subphylum Hexapoda) (six legs, the insects)

3 sections of body: head, thorax, abdomen

Most abundant arthropod. Maybe 30 million species.

Most can fly. 2 large compound eyes, 3 simple eyes (ocelli), one pair antennae.

Legs on thorax, feeding appendages in head.

Veins in wings for strength.

Wings an outgrowth of the cuticle (exoskeleton).

Most have **2 pairs of wings**: Flies (Class Diptera) have **one pair**, second pair are called **halteres**, for balance.

Lice, fleas, non-reproductive ants and termites are **wingless**.

Scales on butterfly wings, **Thin underwings** of beetles used for flight.

Some herbivorous, predaceous, or saprophagous (eat dead stuff). Some parasitic.

Mouthpart variety. What kinds are there?

Spiracles (holes in side of abdomen) with **valves** that close, open to **trachea tubes** for oxygen exchange.

Compound eyes made of thousands of **ommatidia** (mini-eyes)

Pheromones (chemicals), sounds, colors attract mates.

Internal fertilization, some have sperm packets (**spermatophores**)

Metamorphosis during growth.

Hemimetabolous insects : incomplete metamorphosis. Egg, multiple nymphs, to adult . Last nymph develops wings.

Holometabolous insects (80%) Complete metamorphosis. Egg, larva, pupa, adult.

Beneficial insects, harmful insects, medically important insects

DEUTEROSTOMES

Phylum Echinodermata -General Characteristics

1. **Ossicles** = Calcium carbonate plates make **endoskeleton** (under the epidermis). Separated in sea star, fused in sea urchin and sand dollar. Reduced in sea cucumbers.
2. **Water vascular system** with canals leading from madreporite to each arm to ampulla and tube feet.
3. **Pentaradial symmetry** in adults, bilateral symmetry in larval forms. Pentaradial symmetry useful for a sessile life, similar to those with radial symmetry, like sea anemone or jellyfish.
4. Most have **oral and aboral surface**, mouth on bottom is oral, anus and madreporite on top is aboral.
5. Some have **pedicellariae** (little microscopic pinchers that remove debris or may actually be poisonous in sea urchins and deter predators)

Class Asteroidea: Sea stars– tube feet in ambulacral groove on boom of arms, pedicellariae, strong enough to open up a clam with the suction of their tube feet. Stomach everts out to digest the clam while it's still in its shell. Light sensing "eye spot' at tip of each arm. Can regenerate arms.

Class Holothuroidea: Sea cucumbers– stretched out side to side, mouth to anus, rather than flattened like a sea star or sand dollar. Few ossicles so body is softer. 5 rows of tube feet, 3 down, 2 up. Respiratory structures for respiration and excretion. Defense of Tubules of Cuvier that are noxious, sticky, and everted when predator tries to bite them. Feed with tentacles, by trapping particles or grazing on bottom. (remember the pearl fish?!)

Class Echinodea: Sea urchins and sand dollars - Aristotle's lantern for scraping algae or other small particles. Spines of urchin in ball and socket joints, covered in epidermis.

Class Ophiuroidea: Brittle stars– simple tube feet without suckers, and move with whole arms, arms have jointed ossicles, scavenge food, good at regenerating arms.

Class Crinoidea: Crinoids – Sea lilies and feather stars - look plant-like with long, many-branched arms, and filter feed, permanently attached to surface.

Phylum Chordata

Important chordate characteristics:

Notochord – rodlike tissue in the back (dorsal side) for support and muscle attachment. Can bend without shortening and permits side to side undulations (movement). Displaced by vertebrae in most vertebrates.

Dorsal, hollow nerve chord – enlarges at head end (anterior) to form the brain. Produced in embryo by infolding of ectodrmal cells on the dorsal side of the body.

Pharyngeal pouches and slits – from pharyngeal cavity to the outside. Forms gills in aquatic chordates like fish for gas exchange (oxygen in, carbon dioxide out), tadpoles, some salamanders. Filter feeding apparatus in tunicates and lancelets. Forms more advanced structures in tetrapods, like Eustachian tubes, middle ear cavity, tonsils.

Endostyle – a new definitive chordate characteristic. On ventral side of pharyngeal gill pouch. Makes mucus for pharyngeal gill feeders. Forms thyroid gland in other chordates.

Postanal tail – tail extends beyond the anal opening. Has muscles for swimming, used in larval sea squirts (tunicates) and in adult and larval lancelets (Amphioxus) and fish, and is sometimes present and sometimes not present in other groups of tetrapods.

Subphylum Urochordata: Tunicates or sea squirts Retains pharyngeal gill slits and endostyle as adults, lose the other chordate characteristics. Filter feeds with siphons and enlarged pharyngeal gill basket covered in mucus
Subphylum Cephalochordata: Lancelet (*Amphioxus*) All chordate characteristics retained in adult. Filter feeds and burrows into sand.

Subphylum Craniata (Vertebrata) – develop an endoskeleton which permits very large body size, attachment of segmented muscles. Can be cartilage or bone, bone is stronger. Animals shift to active predation in some cases, need bigger brain and protection around it (cranium or braincase). More advanced sense organs (eyes, ears, Eustachian tubes).
Jawless fishes – hagfish and lamprey. No jaws, no real internal skeleton, no paired fins. Pore-like openings to gills, eel-like body.

Hagfish (Class Myxini) – All are marine with body at same salt concentration as seawater, scavenge food from dead or dying organisms. Mostly blind. Secrete lots of mucus to escape predators. Jawless, with teeth on the tongue for rasping. All chordate characteristics, but no vertebrae, even though they are classed as a Subphylum Vertebrata.

Lamprey (Class Cephalospidomorphi) – Half are nonparasitic, eating algae as larvae. Half are parasitic, mostly on fish. Larval form looks a lot like a Lancelet. Marine forms anadromous, reach adulthood in ocean and swim upstream to fresh water to reproduce (spawn). Make nest, shed eggs into nest which are quickly fertilized. Then adults die. Parasitic types attach to fish to suck fluids. Sea Lampreys moved into Great Lakes, ate commercial species like lake trout.

Cartilaginous fishes (Class Chondrichthyes) – sharks and rays

- Skeleton made of cartilage, no mineralized bones
- Tail is asymmetrical (heterocercal)
- Paired pectoral and pelvic fins
- Many rows of teeth, which are shed and regrown continuously
- Placoid scales, made of dentin and enamel like a tooth
- Mouth on ventral side, unlike fish with mouth on the anterior end
- Body is streamlined for easy swimming, and asymmetrical (heterocercal) tail helps
- External gill slits open to the ocean, no covering like a fish has. Spiracles on top of head helps bring water in over the gills. Some sharks must keep swimming to move water over the gills.
- No swim bladder, so sharks have less floating ability compared to bony fish. Extra fats in liver (squalene) in this group for some buoyancy.
- Lateral line, like in fishes, is sensory.
- Ampullae of Lorenzini are electro sensors all over the head to pick up electrical signals from other fish muscle movement.
- 2 chambered heart
- Spiral valve in the intestine to increase surface area for absorption.
- Males have claspers made from edge of pelvic fins for mating (modified copulatory organ). Internal fertilization.

- Know terms oviparous, ovoviviparous, viviparous

- Ray and skate body is flattened top to bottom.
- Pectoral fins are enlarged to form the “wings”.

- Large spiracles on top to get water into the gills.
- Gill slits are on the ventral side.
- Teeth can crush prey.
- Stingrays have venom and spines on tail.
- Electric ray – electric discharge to stun its prey

Bony fishes (Superclass Osteichthyes)

Gills covered by operculum – a bony flap of skin to aid movement of water over the gills. As operculum moves out, water is sucked in the mouth and over the gills, like a bellows. Water movement is continuous.

Gas filled swim bladder keeps fish buoyant and also provides extra oxygen if needed. This becomes a lung in lungfish.

Mouth at anterior end of head, more efficient than shark, can vacuum in food.

Scales embedded in the dermis of skin, unlike shark, whose scales are on the surface.

2 chambered heart. Vessels in close association with gills for oxygen exchange.

Tail is symmetrical (homocercal).

Tail plus body muscles propel the fish quickly through water.

Scales are thinner than shark scales for less drag when swimming (lowers the friction)

Class Sarcopterygii: Non- teleost fish (lobe-finned fishes), like gar or bowfin, can gulp air to supplement gills. Scales of lobe-finned fishes, including the coelacanth, are diamond shaped and harder than other bony fish scales. Lobe-finned fishes have bones in their fins that look similar to 4-legged vertebrates (tetrapods). Lobe-finned fishes are more closely related to tetrapods than they are to the other fishes (ray-finned fishes). Lung fishes and coelacanths are ancestors to tetrapods. Pelvic and pectoral fins are stronger and bonier than regular fish fins.

Class Actinopterygii: Ray finned Fish

Most fishes are Teleosts (96%) (Actinopterygii) Ray-finned fishes

Some can walk across land, some can climb trees

Teleosts have thinner scales than gars and bowfish.

Some fish, like eels and catfish, have no scales at all.

Maximum fish swimming speed = 10 body lengths per second.

W-shaped myomere muscles fibers are efficient at swimming.

Significance of **Tiktaalik**. What are its fish and amphibian characteristics? What was sonic hedgehog from the Inner Fish video, and why was it important?

Class Amphibia

Problems when moving from water to land? See powerpoint.

Adaptations of tetrapods for a life on land. See powerpoint.

Amphibians tied to water. Eggs need to stay moist, larvae develop in water, generally. Larvae have gills.

Ectothermal. Thin, moist skin loses water rapidly. No scales.

3-chambered heart, **double circulation,**

Caecilians – Order Gymnophiona – A tetrapod that has lost its legs. Burrow. Live in tropical forests. Eat worms and invertebrates.

Salamanders – Order Caudata – Small, legs held out at right angles, carnivorous on worms, arthropods and mollusks. Aquatic larvae and terrestrial adults for most, except mudpuppy, which retains juvenile gills (**paedomorphosis**). Get lots of oxygen from their moist skin, which has lots of blood vessels to pick up the oxygen. Some have lungs, most have gills as juveniles. Some have no gills or lungs as adults, just get oxygen through skin.

Frogs and Toads – Order Anura – also breathe through skin, have lungs as adults, gills as tadpoles. Larval stage has tail, adult loses tail. Tadpoles are herbivorous and have special mouth for eating algae. Frogs hibernate in soft mud, breathing through skin. Some hibernate in summer to avoid drying out. Some have antifreeze so they don't die in freezing weather. Some are poisonous. Pigment cells in skin (**chromatophores**) give them their color, either camouflaged or bright colors indicating they are poisonous. Tongue attached to front of mouth and is sticky. Couple of small teeth to hold onto prey, not for chewing. **Amplexus** posture during mating, with external fertilization.

CLASS REPTILIA: THE REPTILES

The reptiles and birds are very closely related: in fact the classes should not be valid taxa, as they are not monophyletic. Regardless, the weight of tradition still causes the two groups to be considered independently.

CHARACTERISTICS OF REPTILES: 7,000 + species

- Body covered with epidermal **scales**
- Paired limbs with (usually) five toes: absent in snakes and some lizards
- Ribs with **STERNUM** (breastbone): forms a thoracic cage
- Lungs
- **3-chambered heart**: crocodilians with a **4-chambered heart**
- **ECTOTHERMIC**
- Paired kidneys: uric acid waste
- **internal fertilization**
- **SHELLED EGGS** – calcareous or leathery. Extraembryonic membranes – **AMNION, CHORION, ALLANTOIS. Yolk sac. NO larvae.**
- **Sex determined by temperature of eggs during development, Not XY chromosomes**

TAXONOMY

- **ORDER TESTUDINES: turtles and tortoises**

Enclosed in shells of a dorsal **CARAPACE** and a ventral **PLASTRON. No teeth.**
Carapace encloses vertebrae and ribs

- **ORDER SQUAMATA: lizards and snakes**

95% of all known living reptiles
KINETIC skull, quadratojugal hinge
Snakes are limbless and lack both pelvic and pectoral girdles (remnants of pelvic girdle in constrictors)
Some are venomous, pit vipers sense heat

- **ORDER CROCODILIA: crocodiles, alligators and caymans**

Bony palate to separate mouth from nasal cavity
Eyes and nostrils on ventral side of head
4 chambered heart

ORDER AVES: birds

Adaptations for flight: Air sacs, wings, feathers, fast metabolism, hollow bones, enlarged sternum for flight muscle attachment, single ovary and oviduct, lay only one egg a day.
4 chambered heart like crocodilians
Endothermic ("warm-blooded")
Beaks and feet are adapted to feeding preferences.
Lots of parental care (sitting on eggs, feeding hatchlings, protecting babies)

CLASS MAMMALIA

CH. 34.6, 34.7
Mammals

- **MILK**: The production of milk occurs in specialized tissue.
- **HAIR**: All mammals have hair at some point in their development
- Single jaw bone (**DENTARY**): This jaw bone holds the lower teeth, and is connected to strong muscles which increase the strength of lower jaw movements
- Three inner ear bones: the **STAPES** (stirrup), **INCUS** (anvil), and the **MALLEUS** (hammer)
- Seven **CERVICAL** (neck) vertebrae
- Fully Muscular Diaphragm: increases efficiency of gaseous exchange, separates thoracic from abdominal cavity
- Secondary **PALATE (roof of mouth)** separates air passage and feeding area
- Dioecious, internal fertilization, embryo attached via **PLACENTA** to the **UTERUS** (womb) (except monotremes), viviparous. Extensive parental care.
- Homeothermic and endothermic (body temp. produced by metabolism and kept relatively constant)

There are three major subdivisions of living mammals: the monotremes, the marsupials, and the placental mammals.
ORDER MONOTREMATA – egg laying mammals
Represented by only 3 living species, including the duckbill platypus and the echidna. Lack separate external openings for gut, ureters, and reproductive tract. Similar to the reptiles and birds, all three empty into a single chamber, the **CLOACA.** After the young hatch from the egg, they are fed on milk.
ORDER MARSUPIALIA – marsupials, pouched mammals
Mostly Australian. Young born at an early stage of embryonic development, crawl to the pouch (MARSUPIUM), and are nourished on milk until independent.
(INFRACLASS EUTHERIA) – the viviparous, placental mammals (the rest of the mammals), including human evolution and primate characteristics.

Ecdysozoa

- Separation from Lophotrochozoa supported by both molecular data and morphology
- **Defining characteristic: Ecdysis** – molting
- All ecdysozoans possess a **cuticle** for support and protection – must SHED to grow
- Some have **metamorphosis**
- They can survive harsh conditions with **cryptobiosis** (like tardigrades)
- **Two main phyla – NEMATODA and Arthropoda**

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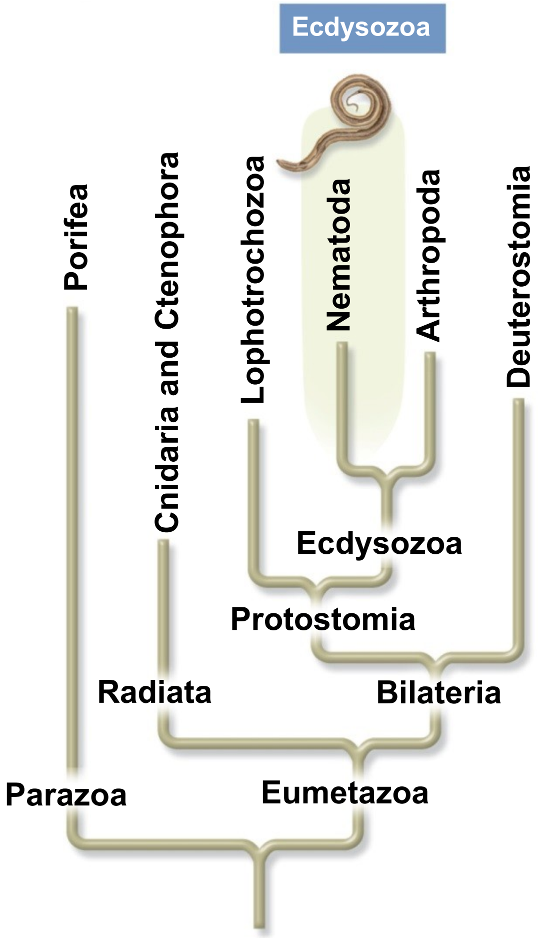
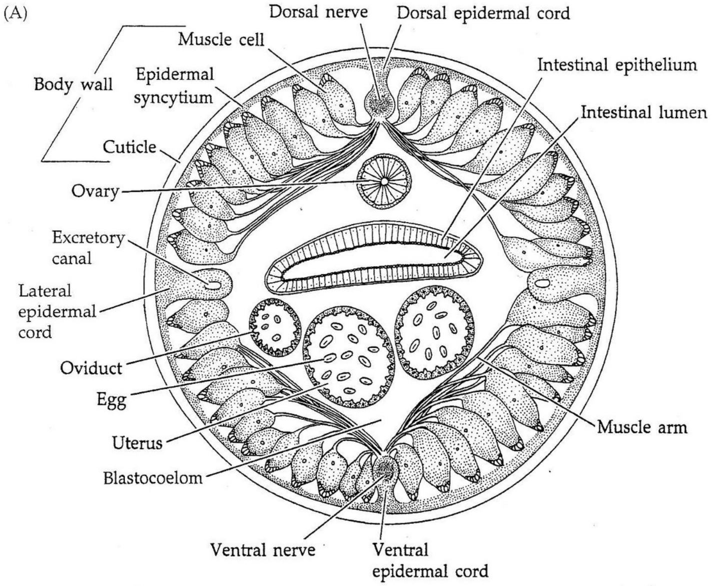


Phylum Nematoda - Roundworms

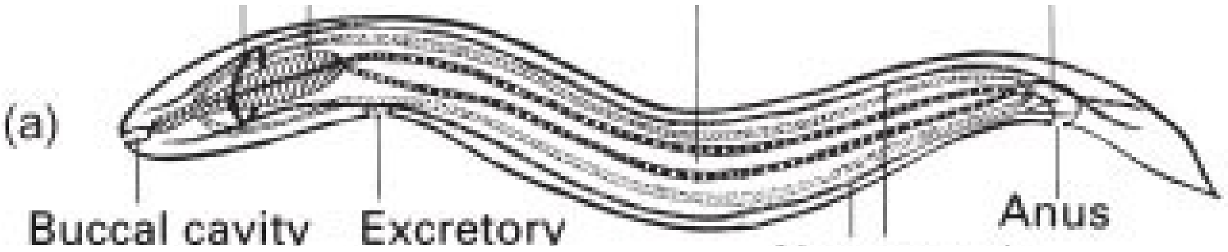
This is the major PSEUDOCOELOMATE phylum. The pseudocoel is derived from the original embryonic BLASTOCOEL.

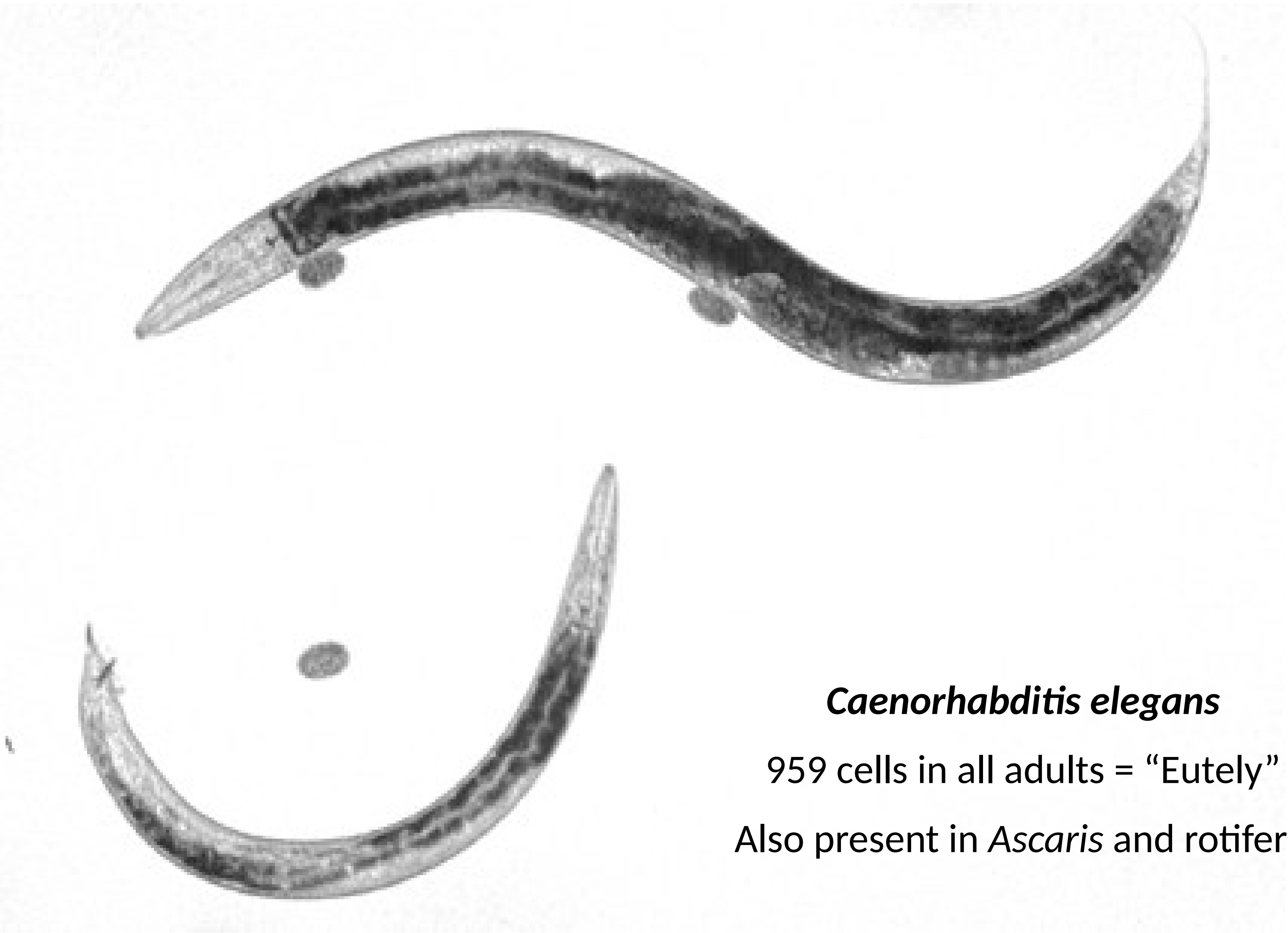
- In nearly all habitats from poles to tropics - there are many animal and plant parasitic species
- Bilateral, cylindrical in cross section, unsegmented
- Over 20,000 species (many more undiscovered)
- Tough **collagen cuticle** covers body
- Longitudinal but not circular muscles



Phylum Nematoda - Roundworms

- Pseudocoelom acts as **hydrostatic skeleton** and as a circulatory system
- Complete “tube-within-a-tube” digestive tract, with muscular pharynx.
- Many nematodes sp. have same number of cells = “eutely”





Caenorhabditis elegans

959 cells in all adults = “Eutely”

Also present in *Ascaris* and rotifers

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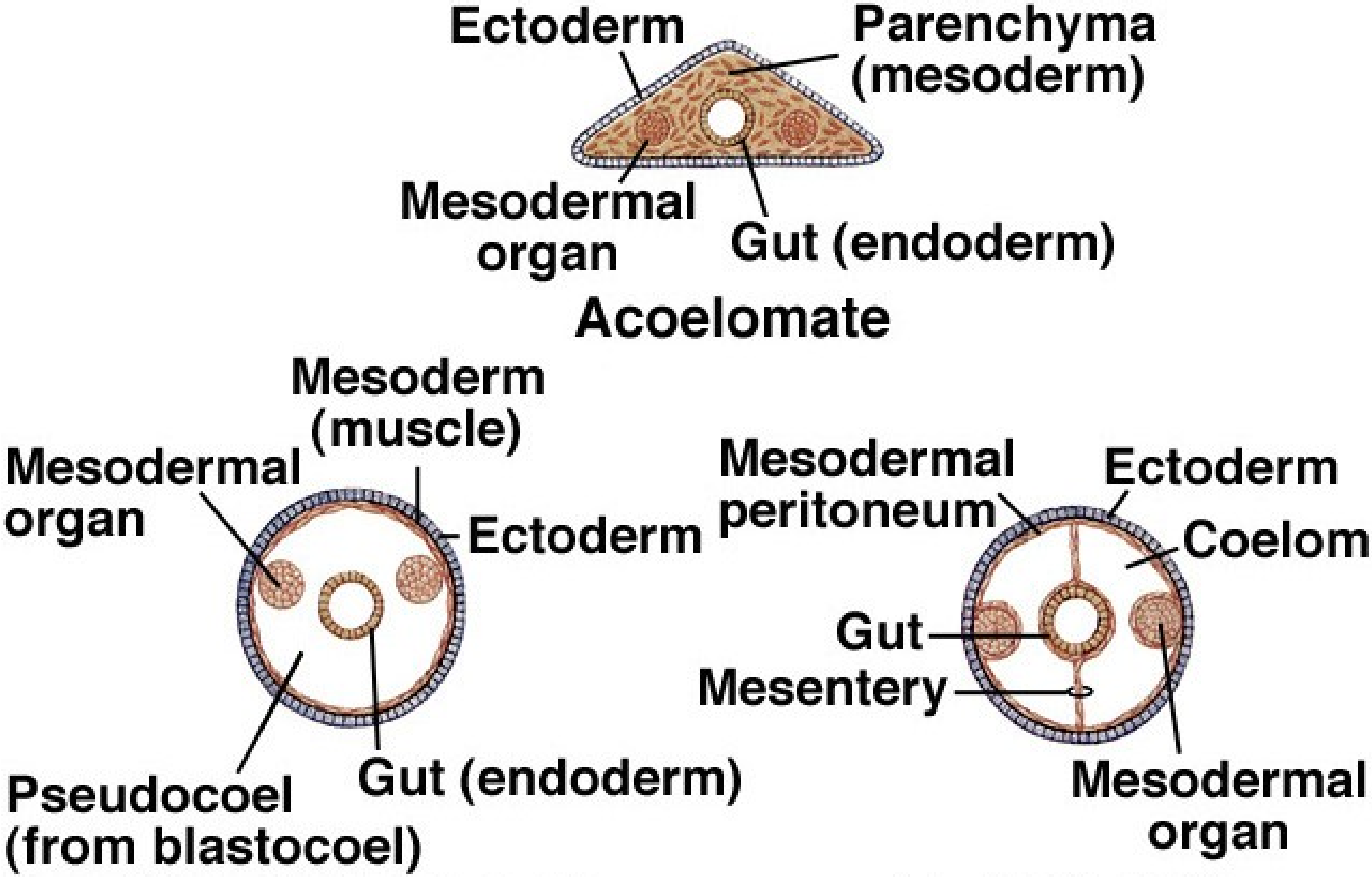
Animal body plans

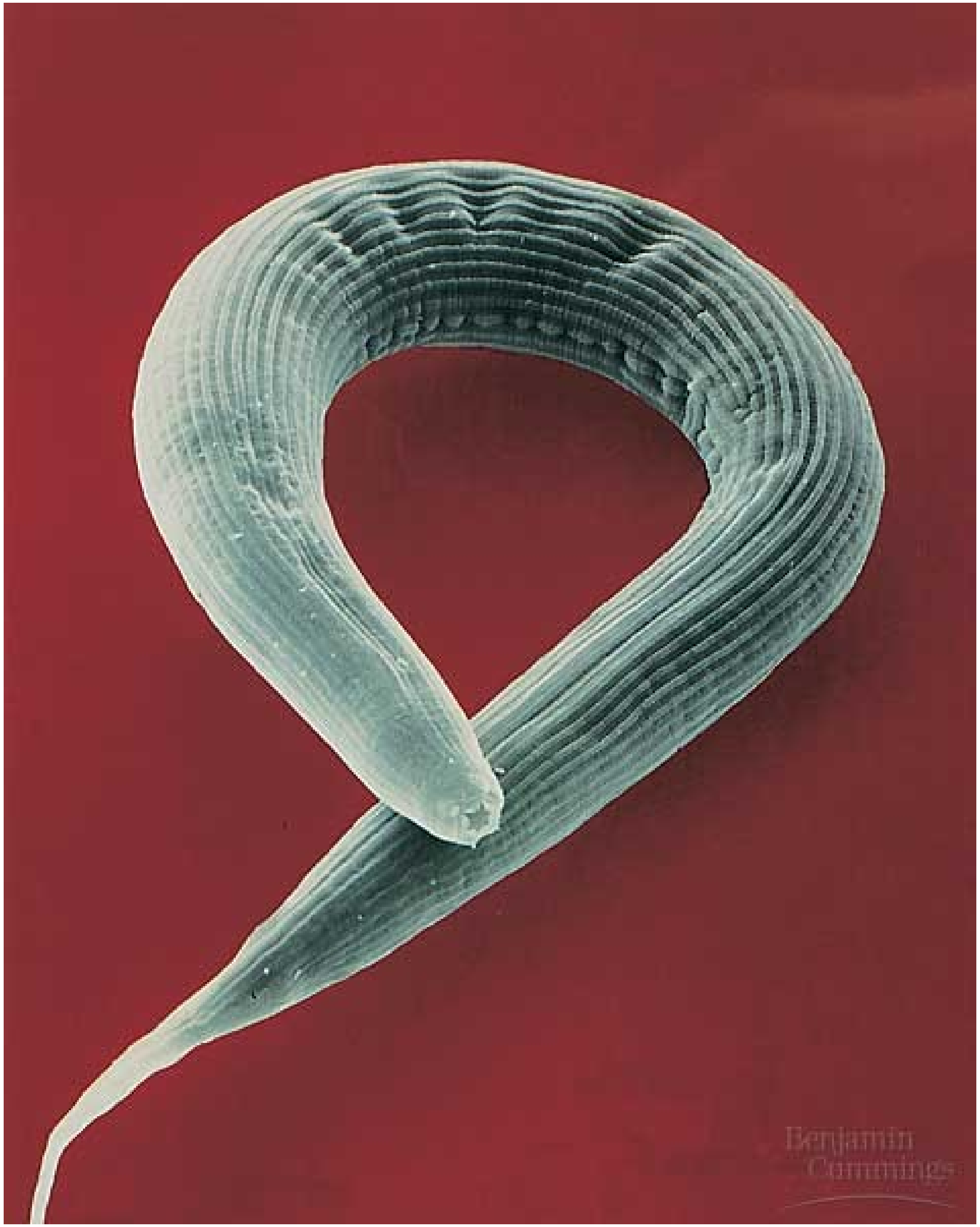


Acoelomate

Pseudocoelomate

Eucoelomate

Free-living nematode



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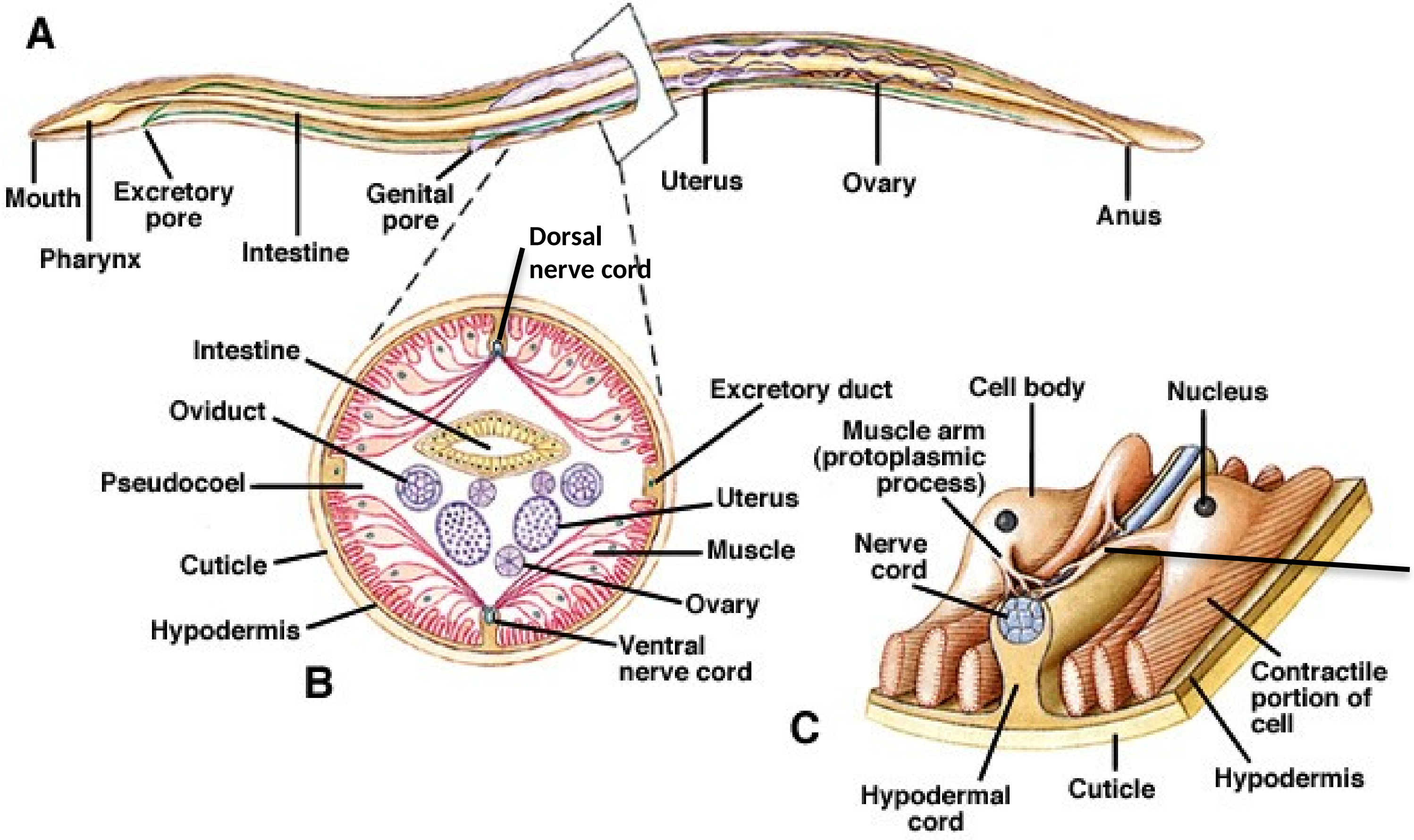
Structures of a nematode



Muscles branch to nerves, rather than nerves branching out to muscles

***Ascaris* sp. female**

Representative Nematode Parasites

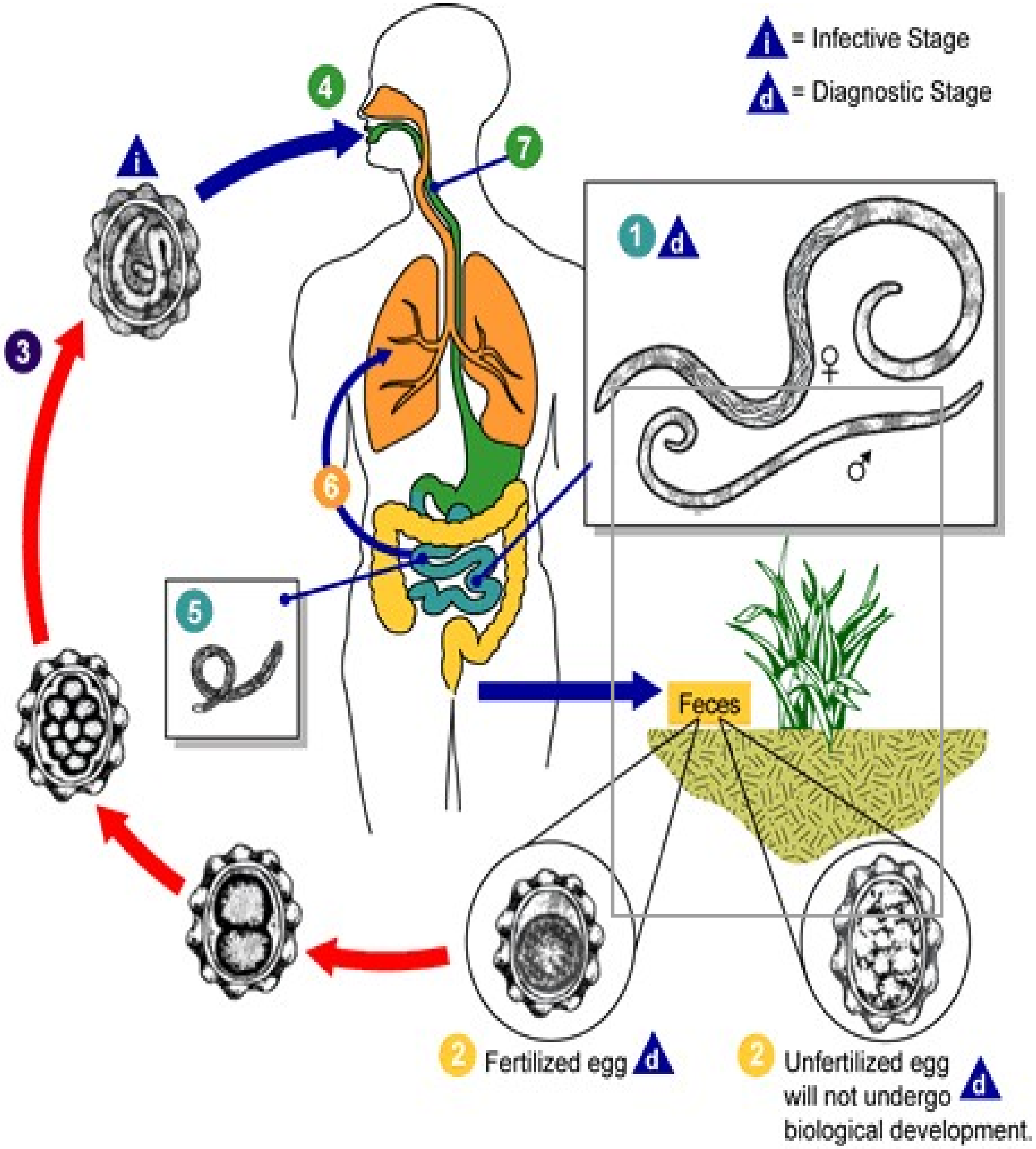
Representative Nematode Parasites

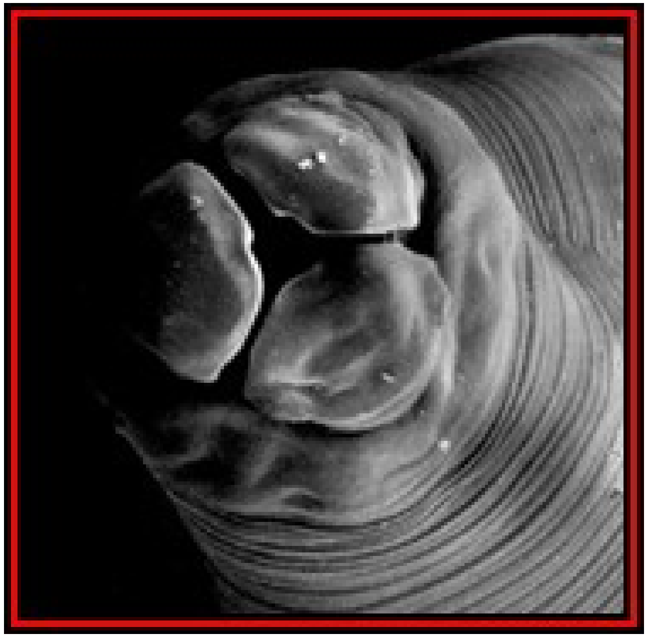
- Some are parasites of humans
  - Most are tropical

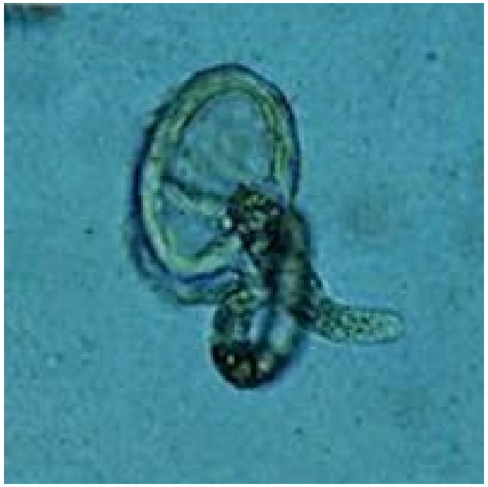
- *Ascaris lumbricoides*
  - Occurs in *up to 25% of people* in some areas of the *southeastern U.S.*
  - More than *1.27 billion affected worldwide*
  - *Ascaris suum* is found in pig intestines
  - A female *Ascaris* may lay *200,000 eggs a day*, which pass out in host's feces

Representative Nematode Parasites

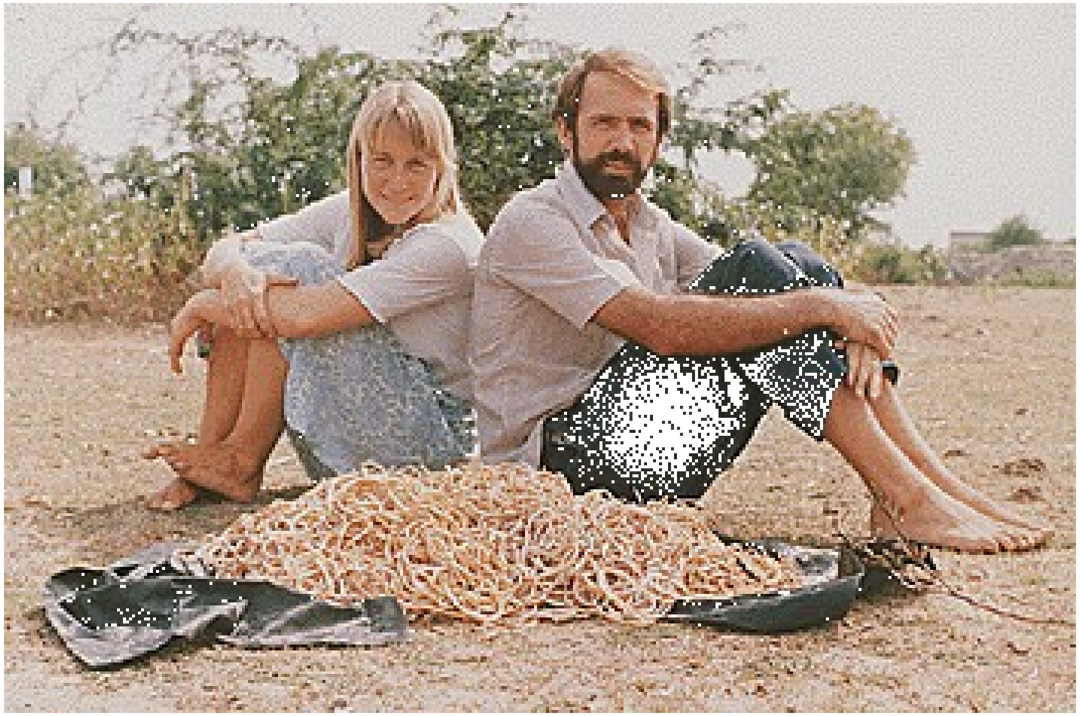
- *Survive for long periods in soil*
- When humans eat undercooked vegetables contaminated with shelled juveniles, or when children put soiled fingers or toys in their mouths, consumed juveniles hatch, and burrow through intestinal wall
- Carried through the lymphatic system and bloodstream to the lungs, they enter into alveoli causing pneumonia and are carried up through tracheae into throat
- Coughed up and swallowed, they mature in the small intestine
- Adults feed on intestinal contents and *may block the intestines*
- Females may produce 200,000 eggs per day


i = Infective Stage
d = Diagnostic Stage
4
7
i
1 d
♀
♂
3
6
5
Feces
2 Fertilized egg d
2 Unfertilized egg will not undergo biological development. d



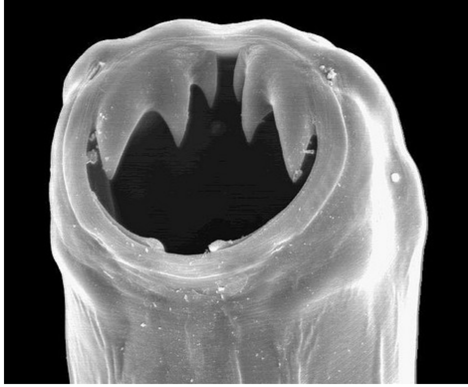


Ascaris

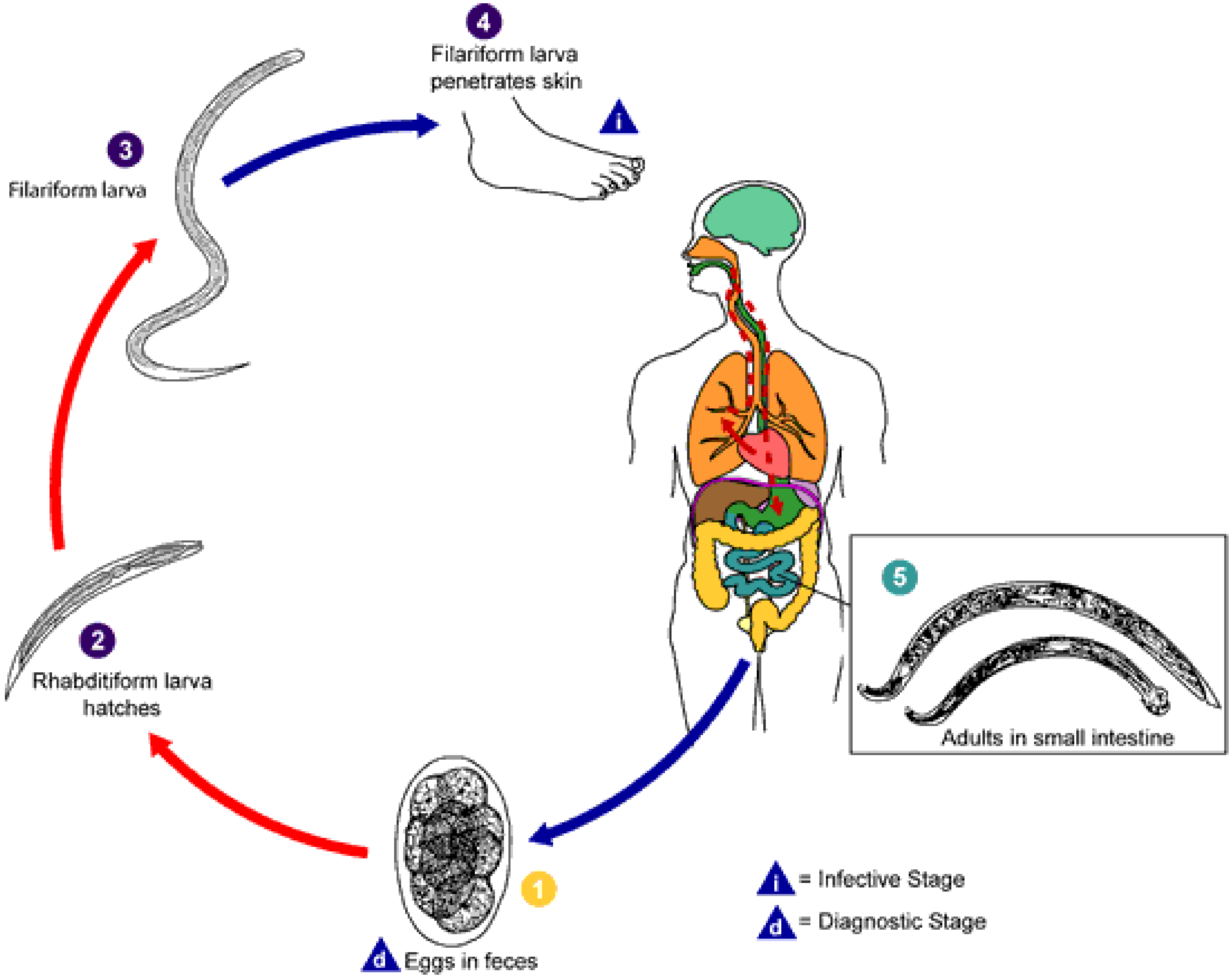


Ascaris

Representative Nematode Parasites



- *Hookworms*
  - Anterior end of these small worms has a *hook-like curve*
  - *Necator americanus,* most common hookworm.
  - Large plates in mouth cut into intestinal wall and suck host’s blood and cling to intestinal wall
  - Pump through more blood than they digest
    - Heavy infections cause anemia
  - Eggs pass out in feces and *juveniles hatch in soil*
  - If human skin comes in contact with soil, infective juveniles **burrow through skin** to blood
  - Travel in blood through bloodstream to lungs, are coughed up to be swallowed, and mature in the intestine



Hookworm life cycle

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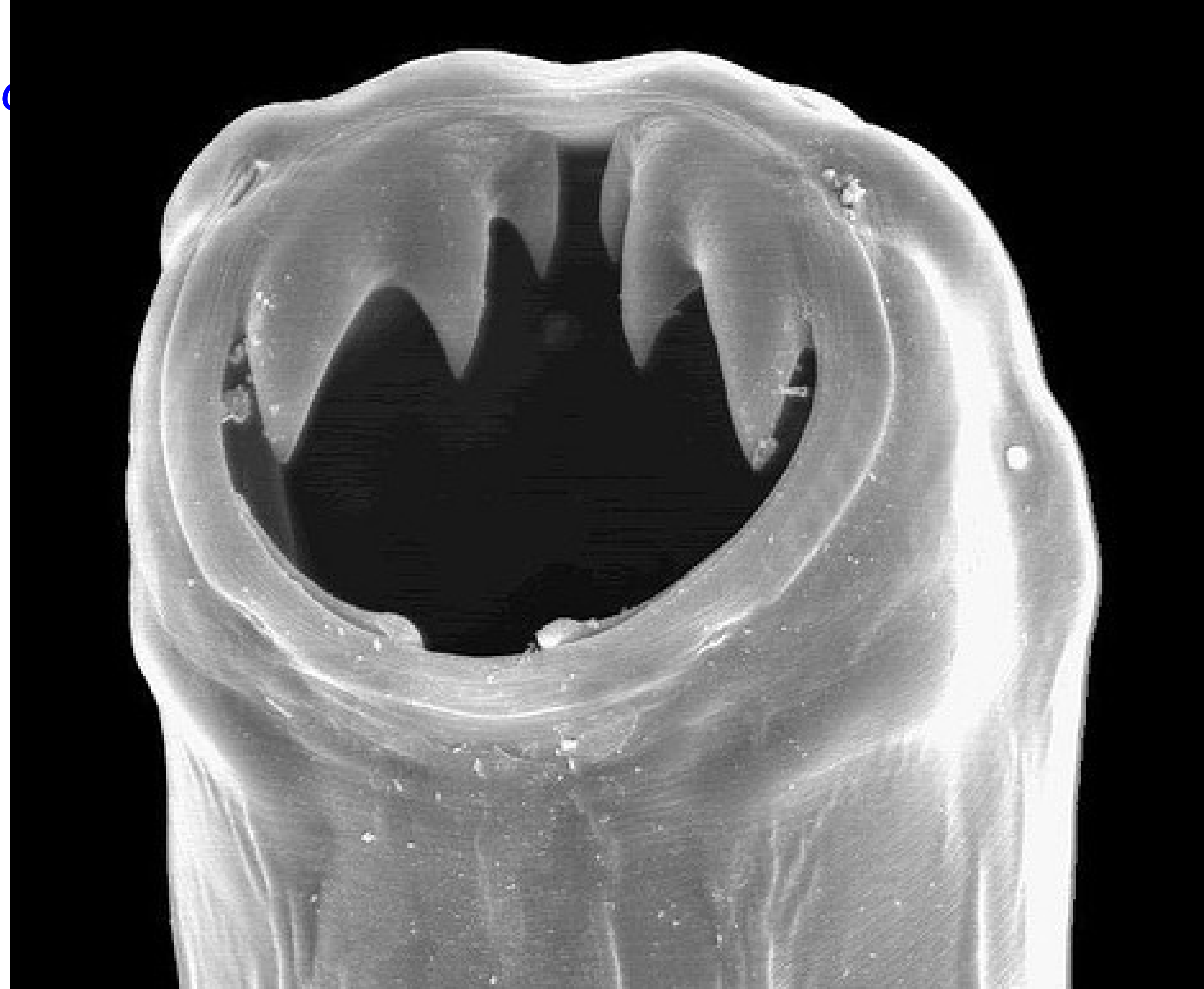
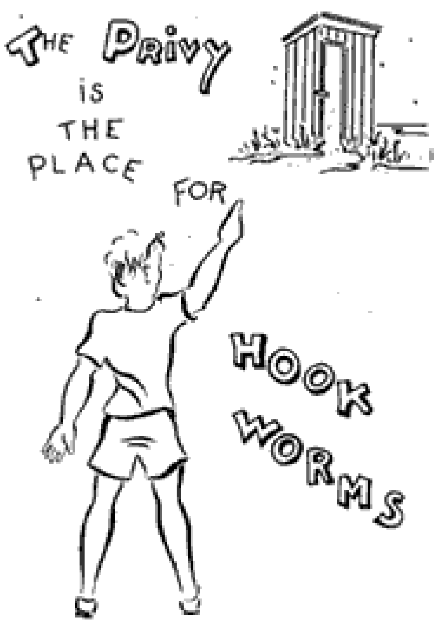


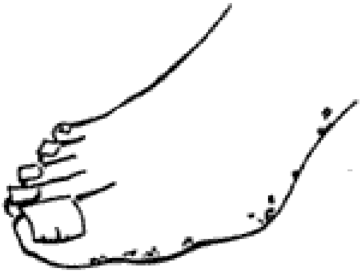


THE **PRIVY** IS THE PLACE FOR **HOOKWORMS**

HOOKWORMS ARE SO **TINY**

YOU CAN SCARCELY SEE THEM

HOOKWORMS LIE ON THE DAMP GROUND AND WAIT FOR YOU TO STEP ON THEM WITH **BARE FEET**



THEY BORE THROUGH THE BARE SKIN AND OFTEN LEAVE LITTLE **SORES** WHERE THEY HAVE ENTERED

THEY TRAVEL THROUGH YOUR BODY AND GET INTO YOUR INTESTINES

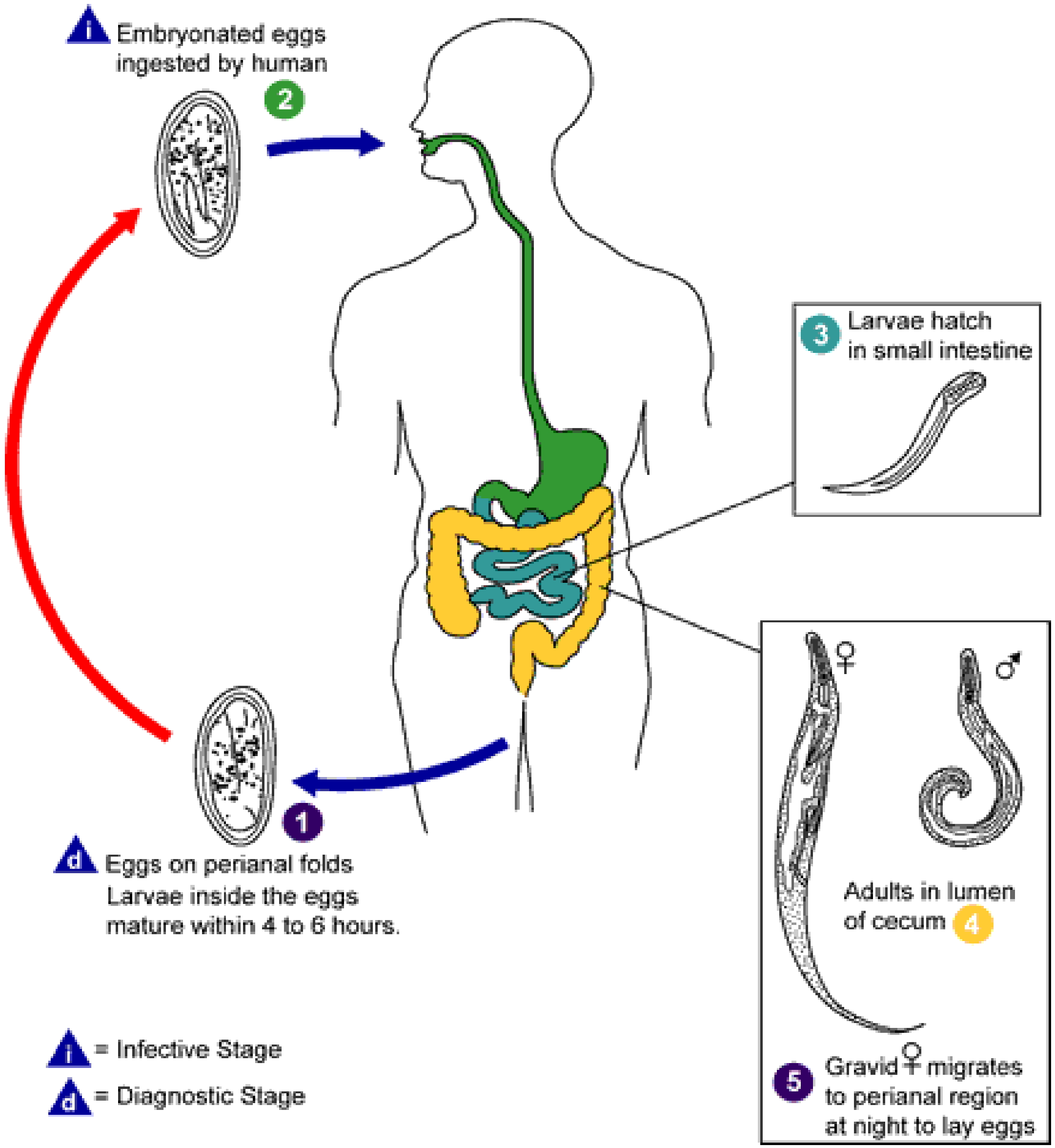
YOU FEEL SICK!

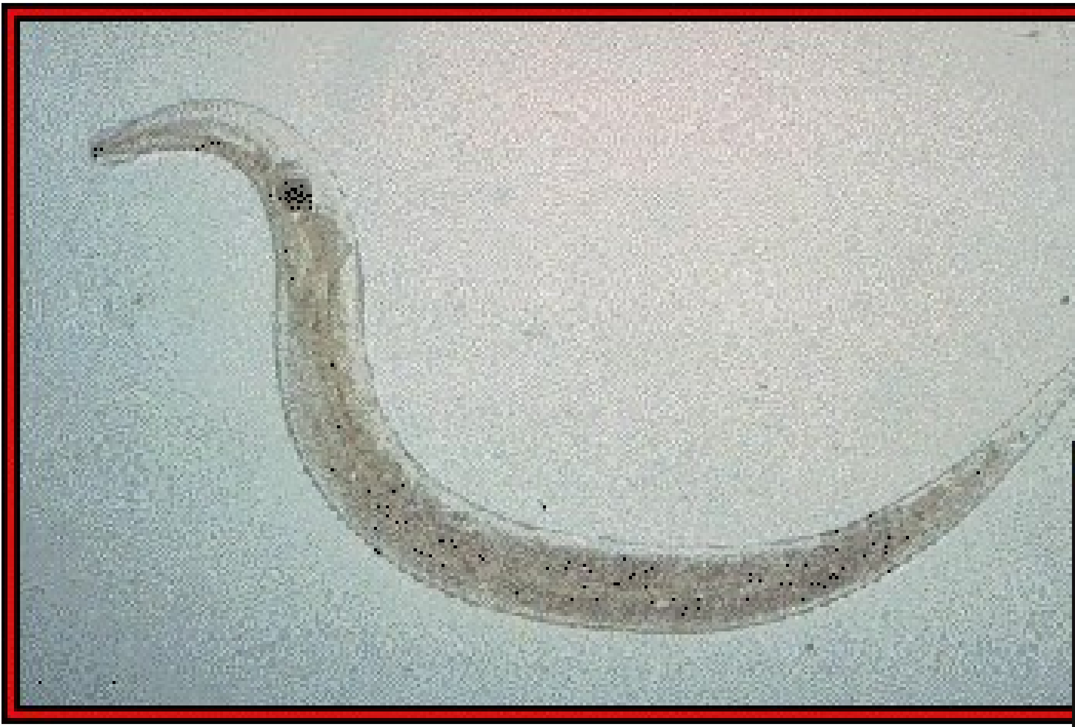
YOU GET **THIN** AND YOU FEEL SO **TIRED** AND **STUPID**

Representative Nematode Parasites

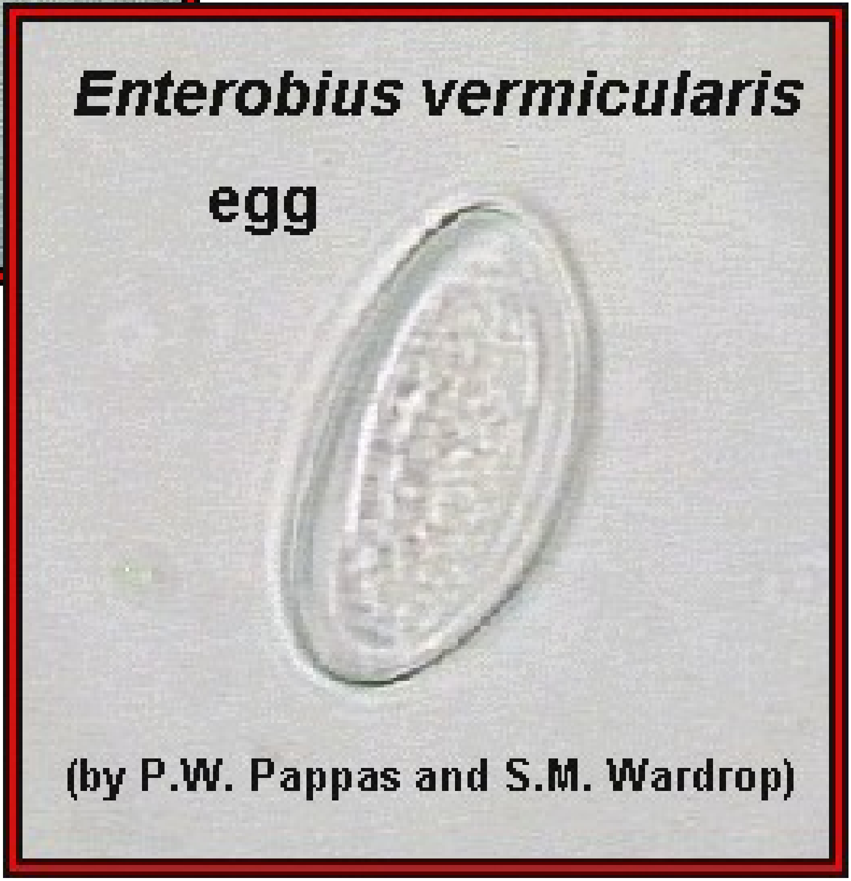
- *Pinworms*
  - Most *common worm parasite in the U.S.*
  - Adults live in large intestine
  - Females, about 12 mm in length, migrate to *anal region* at night and lay eggs just outside, causing itching
  - Little kids scratching the anal region *contaminate hands and bedclothes*
  - Eggs develop rapidly and become infective *within six hours at body temperature*
  - Little kids suck on fingers, they are swallowed, hatch in duodenum and mature in large intestine

HUMAN PINWORM – *Enterobius vermicularis*


i Embryonated eggs ingested by human 2
3 Larvae hatch in small intestine
♀ ♂
Adults in lumen of cecum 4
5 Gravid ♀ migrates to perianal region at night to lay eggs
1
d Eggs on perianal folds Larvae inside the eggs mature within 4 to 6 hours.
i = Infective Stage
d = Diagnostic Stage

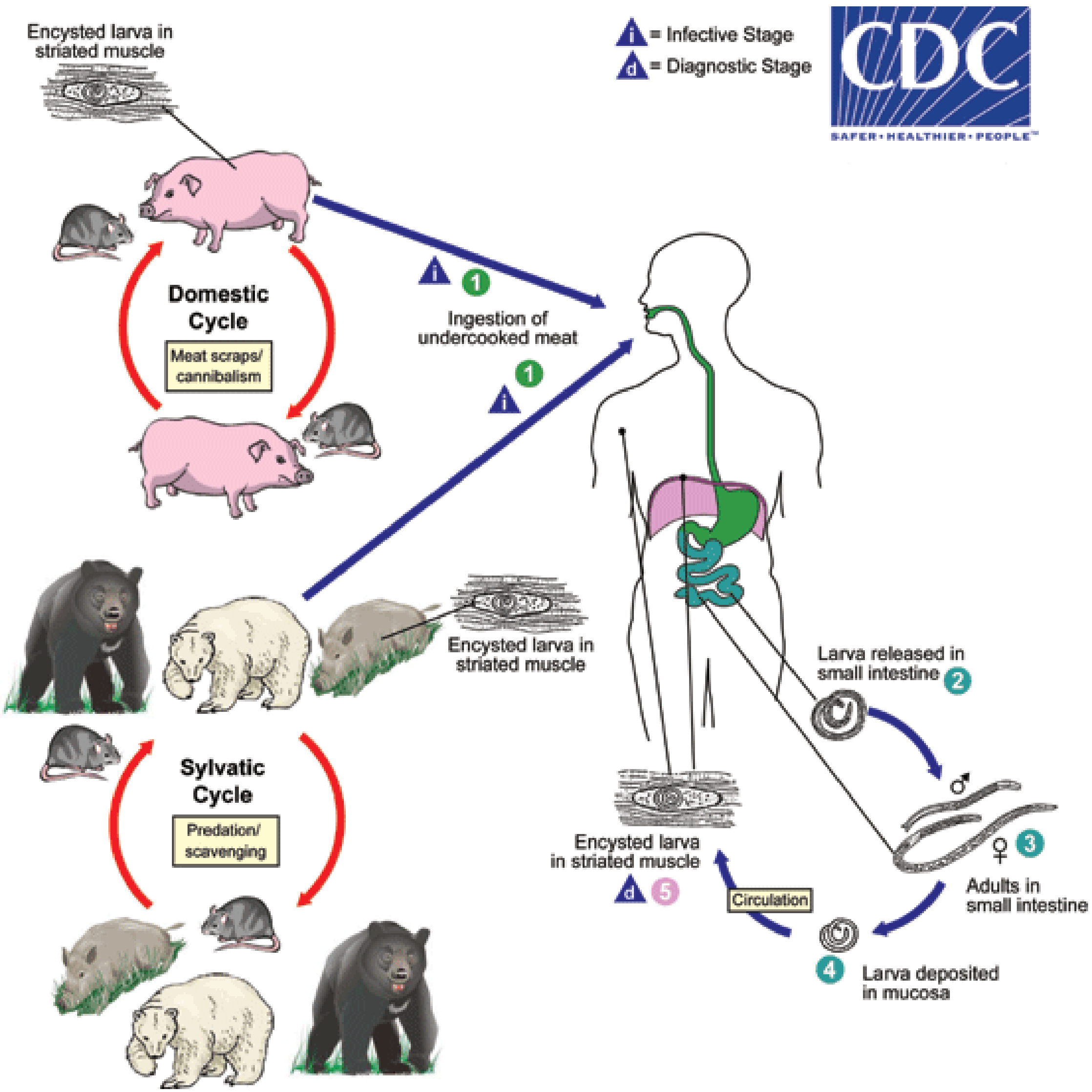


Enterobius vermicularis **– adult pinworm**

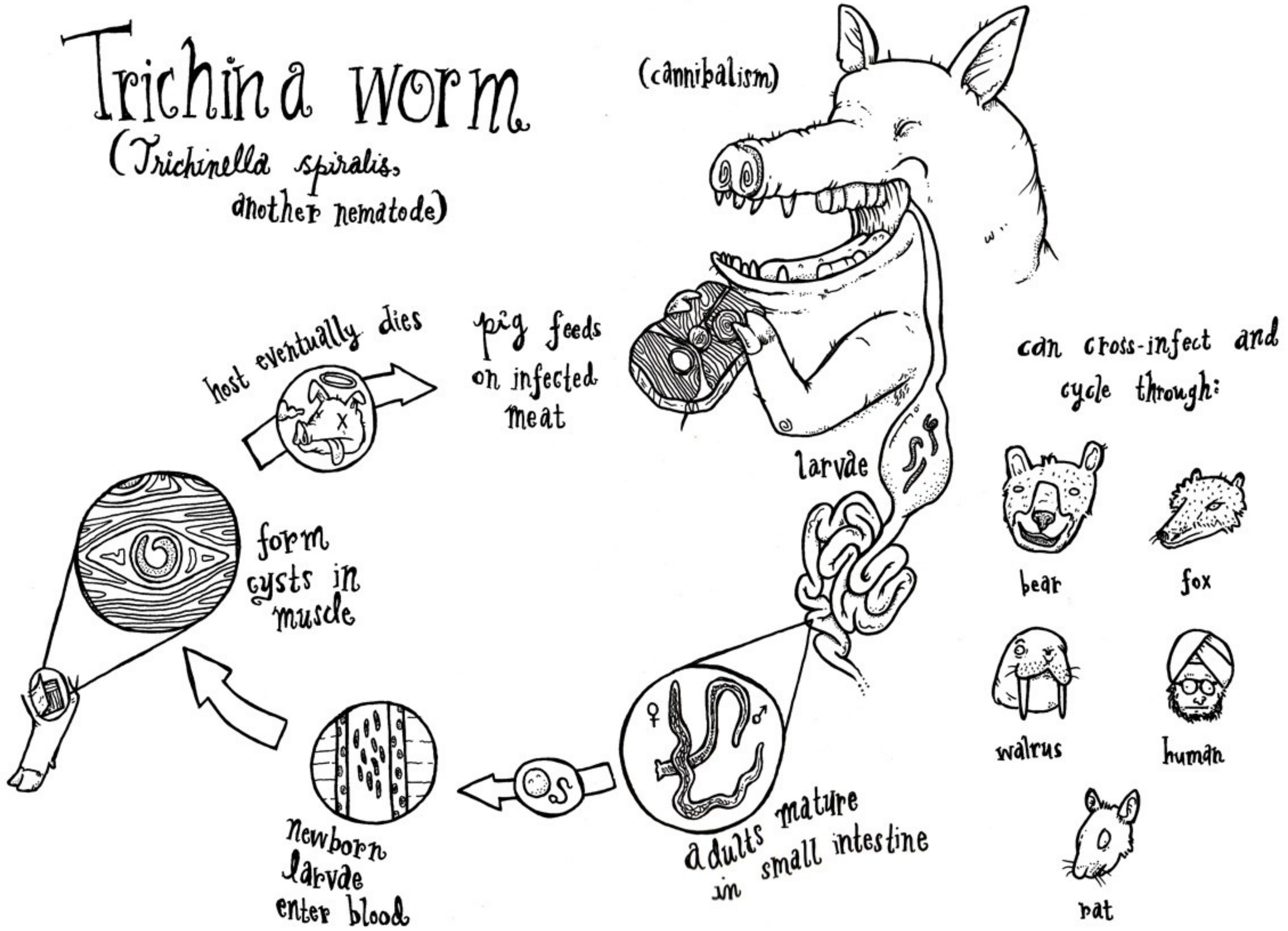


Trichinella

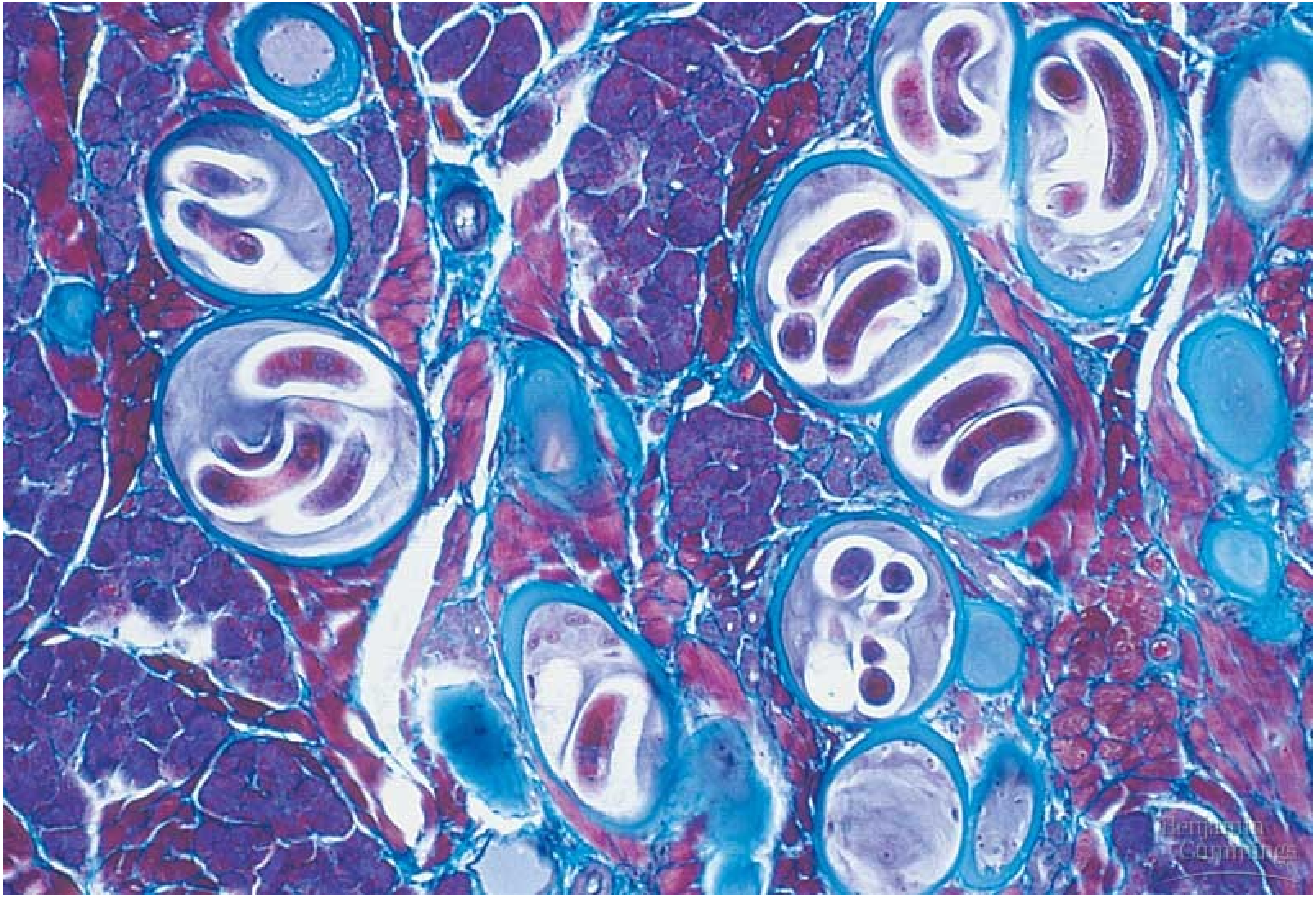
- “Trichinellosis is caused by the ingestion of undercooked meat containing encysted larvae of *Trichinella* species.
- 1. After exposure to gastric acid and pepsin, the larvae are released from the cysts.
- 2. They invade the small bowel mucosa where they develop into adult worms.
- 3. Females are longer than males (2.2mm to 1.2mm). Life span in small bowel 4 weeks.
- 4. After 1 week, females release larvae that ->->->
- 5. migrate to striated muscles where they encyst.
- Encyst in tongue, around eyes, between ribs, sometimes heart and brain.



Encysted larva in striated muscle
i = Infective Stage
d = Diagnostic Stage
CDC
SAFER • HEALTHIER • PEOPLE™
Domestic Cycle
Meat scraps/ cannibalism
i 1
Ingestion of undercooked meat
1 i
Encysted larva in striated muscle
Sylvatic Cycle
Predation/ scavenging
Larva released in small intestine 2
♂
♀ 3
Adults in small intestine
Encysted larva in striated muscle
d 5
Circulation
4 Larva deposited in mucosa


Trichina worm
(Trichinella spiralis,
another nematode)
(cannibalism)
pig feeds
on infected
meat
larvae
adults mature
in small intestine
♀
♂
newborn
larvae
enter blood
form
cysts in
muscle
host eventually dies
can cross-infect and
cycle through:
bear
fox
walrus
human
rat

Parasitic nematode, *Trichinella spiralis*



Benjamin Cummings

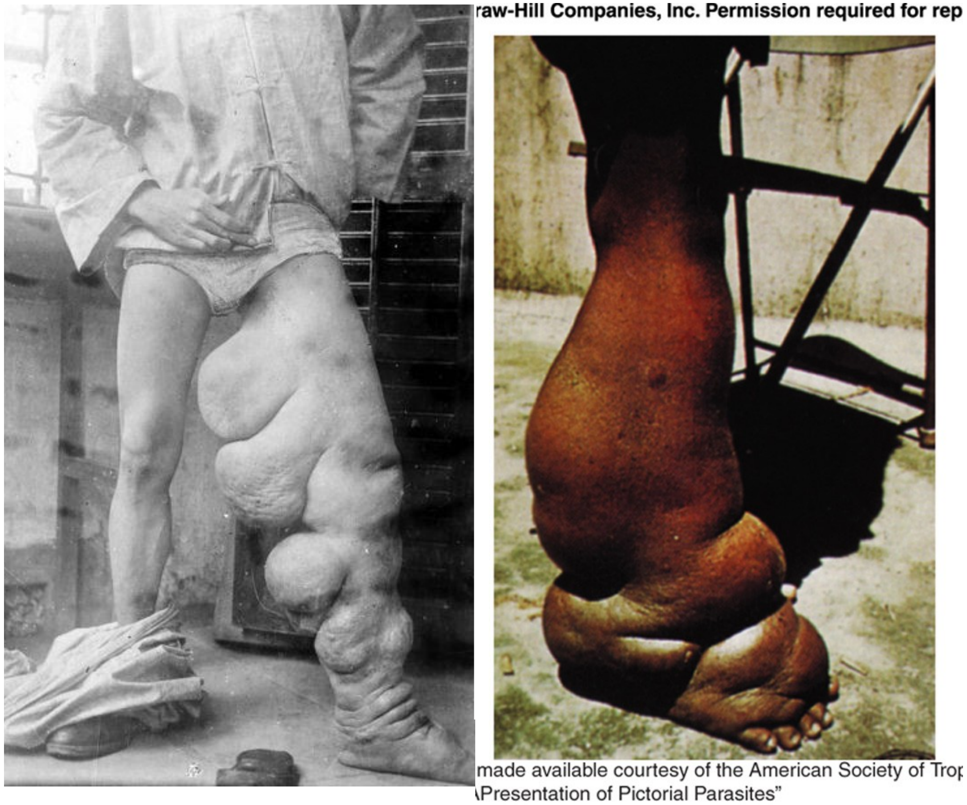
Trichinella, latest cases

Date: Fri 25 Oct 2013
Source: CBC (Canadian Broadcasting Corporation) News [edited]

Health officials in Nunavik [region, Quebec], are trying to figure out the source of a trichinellosis outbreak in Inukjuak [Nunavik]. Since early October [2013], about 15 people have exhibited symptoms of the illness caused by a parasite sometimes found in raw meat of animals Including walrus and polar bear. 2 people have been hospitalized.

Other Nematode Parasites

- Elephantiasis is caused by repeated exposure to filarial worms (*Wuchereria*).
  - Swelling and growth of connective tissue causes enormous swelling of body parts - scrotum, legs, arms
- Some species live in your lymph system and can block the vessels.
- Spread by mosquitos.



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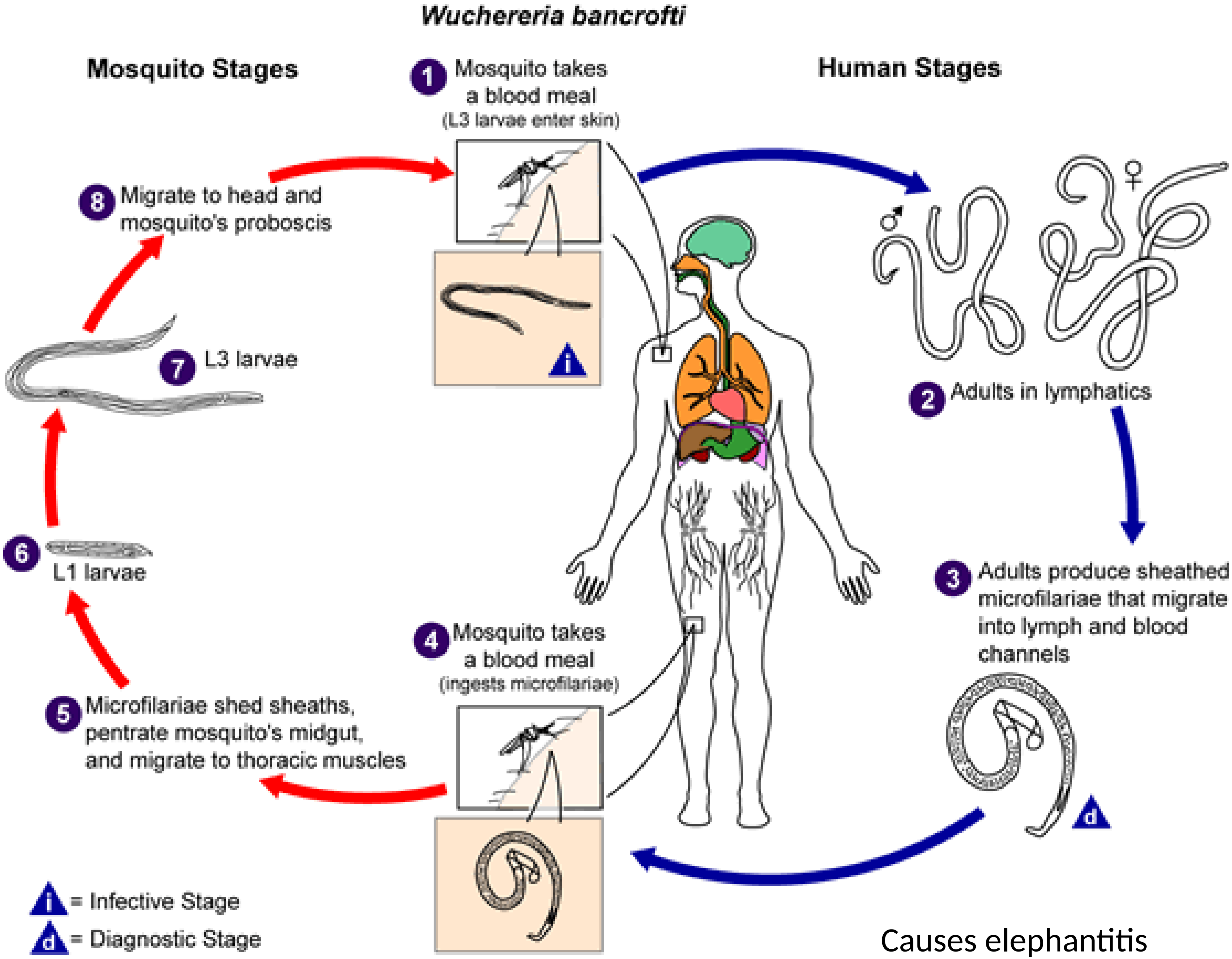
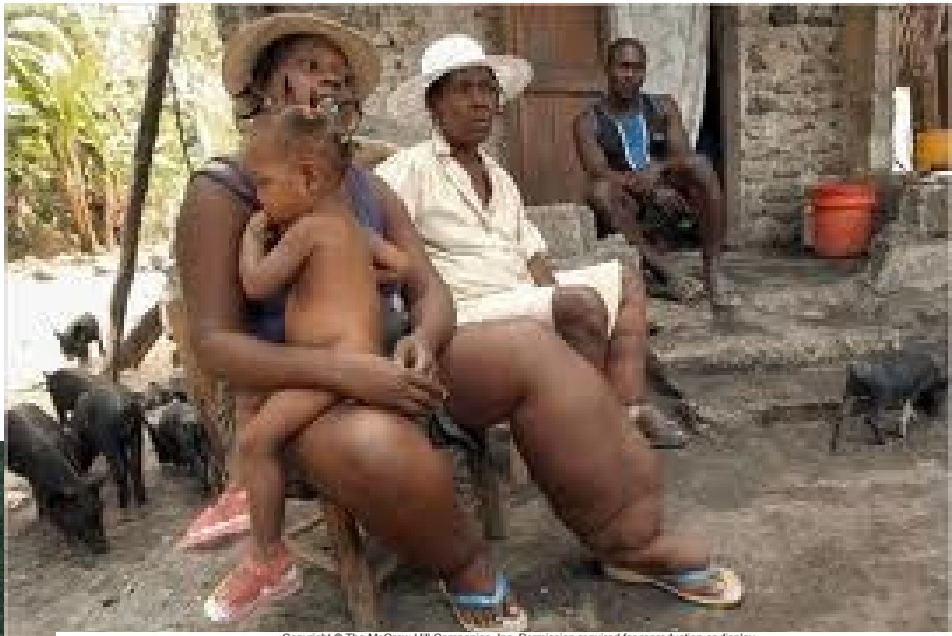
made available courtesy of the American Society of Trop
Presentation of Pictorial Parasites"


Wuchereria bancrofti
Mosquito Stages
Human Stages
1 Mosquito takes a blood meal (L3 larvae enter skin)
2 Adults in lymphatics
3 Adults produce sheathed microfilariae that migrate into lymph and blood channels
4 Mosquito takes a blood meal (ingests microfilariae)
5 Microfilariae shed sheaths, pentrate mosquito's midgut, and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and mosquito's proboscis
♂
♀
i
d
i = Infective Stage
d = Diagnostic Stage

Causes elephantitis

Wuchereria - elephantitis



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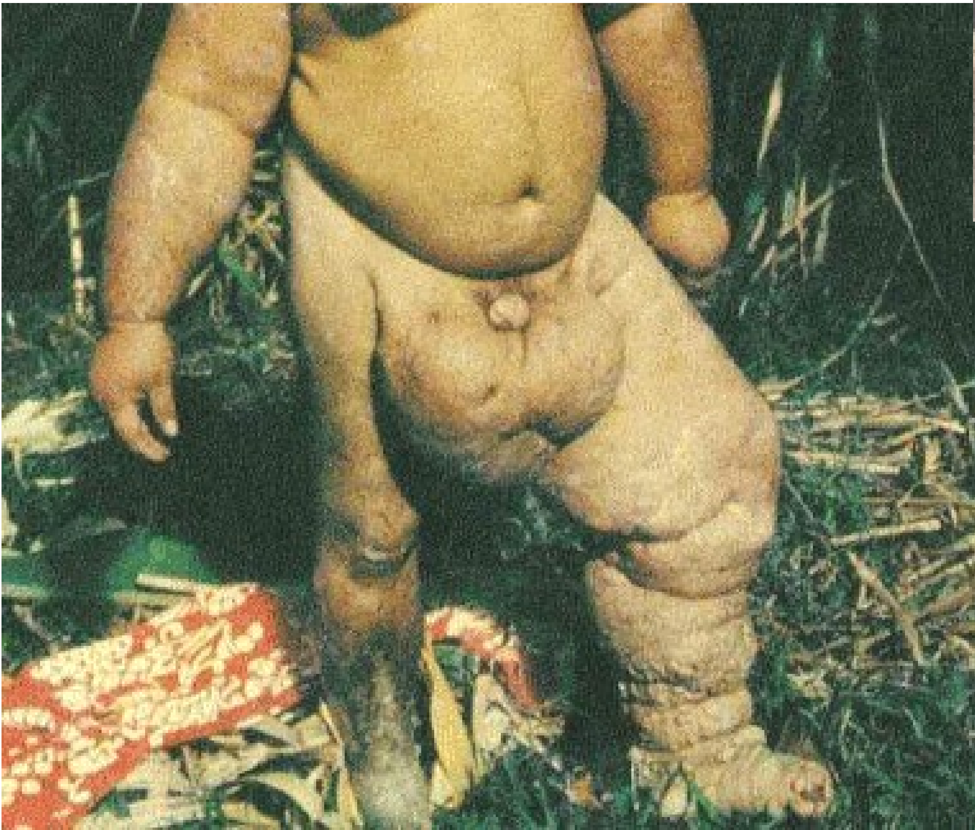
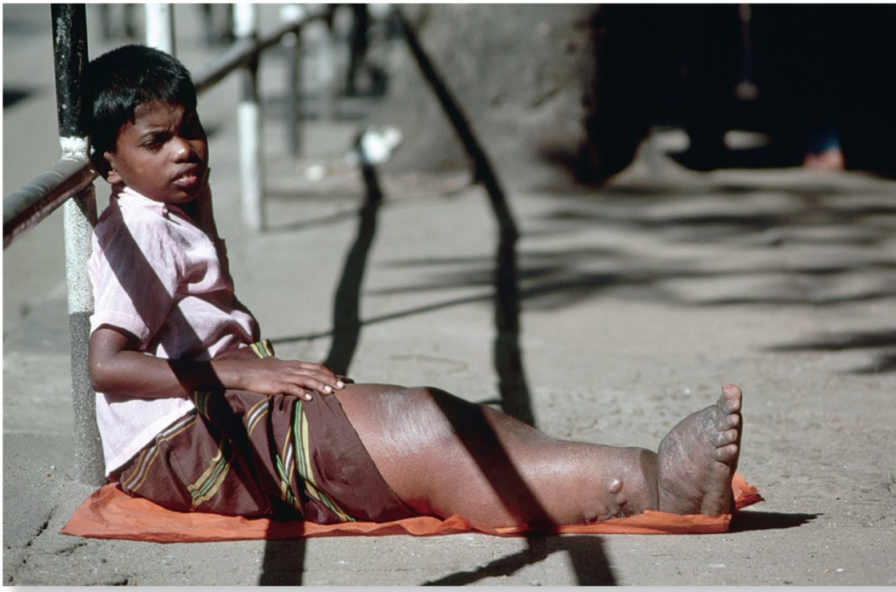
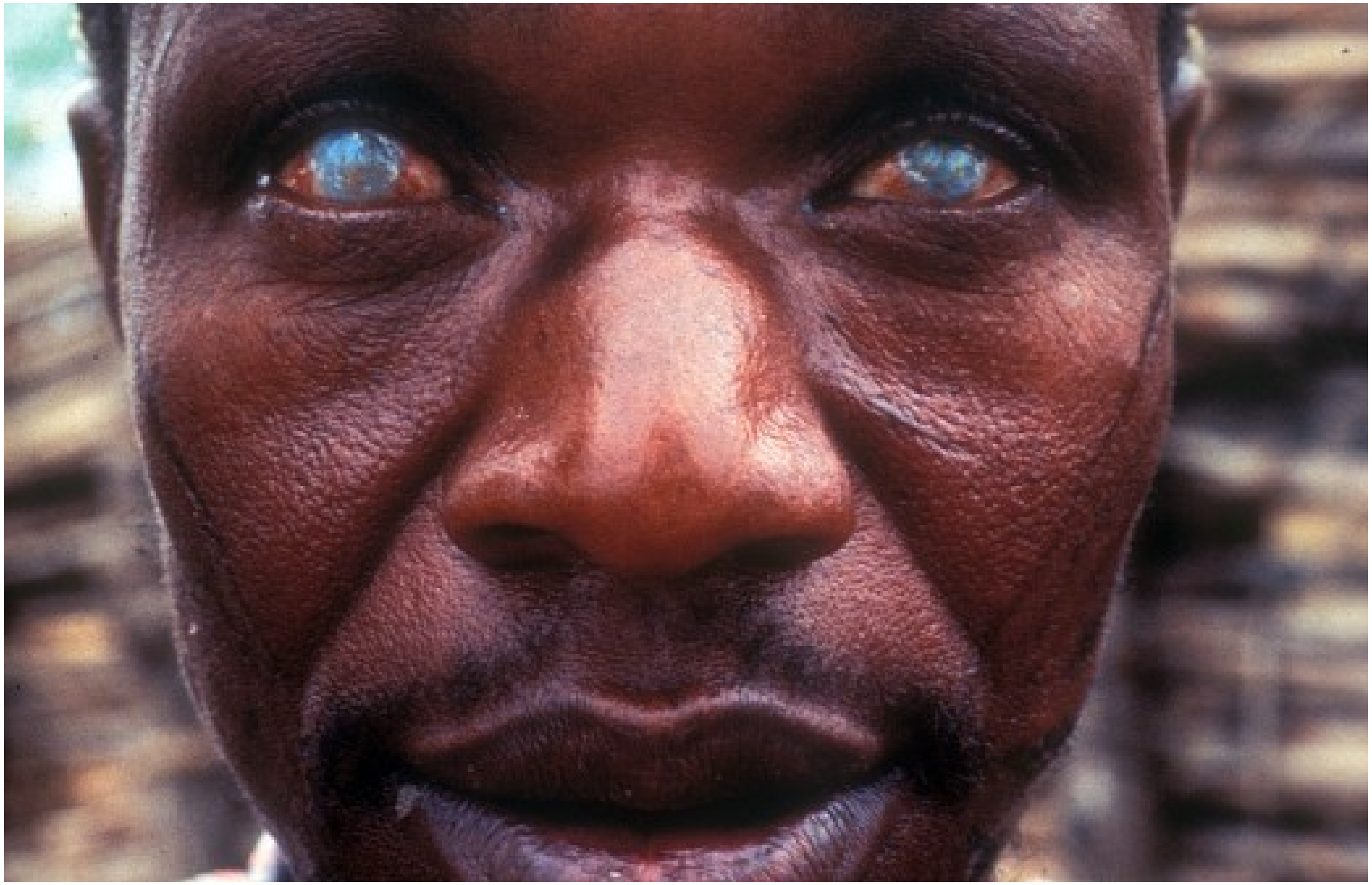




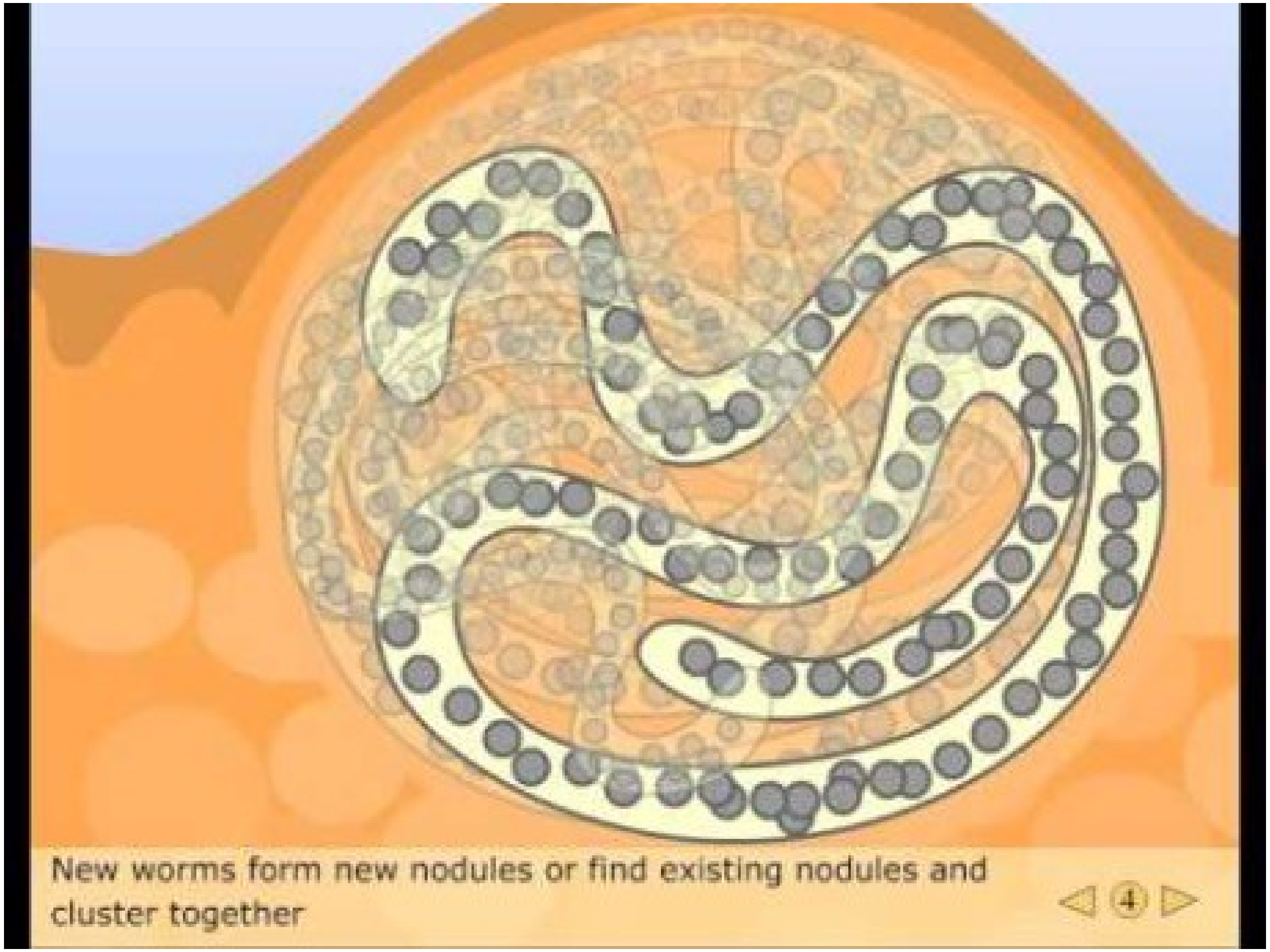
© Johnathan Smith

Onchocerciasis – river blindness



River blindness or onchocerciasis is carried by black flies and infects 37 million people in tropics

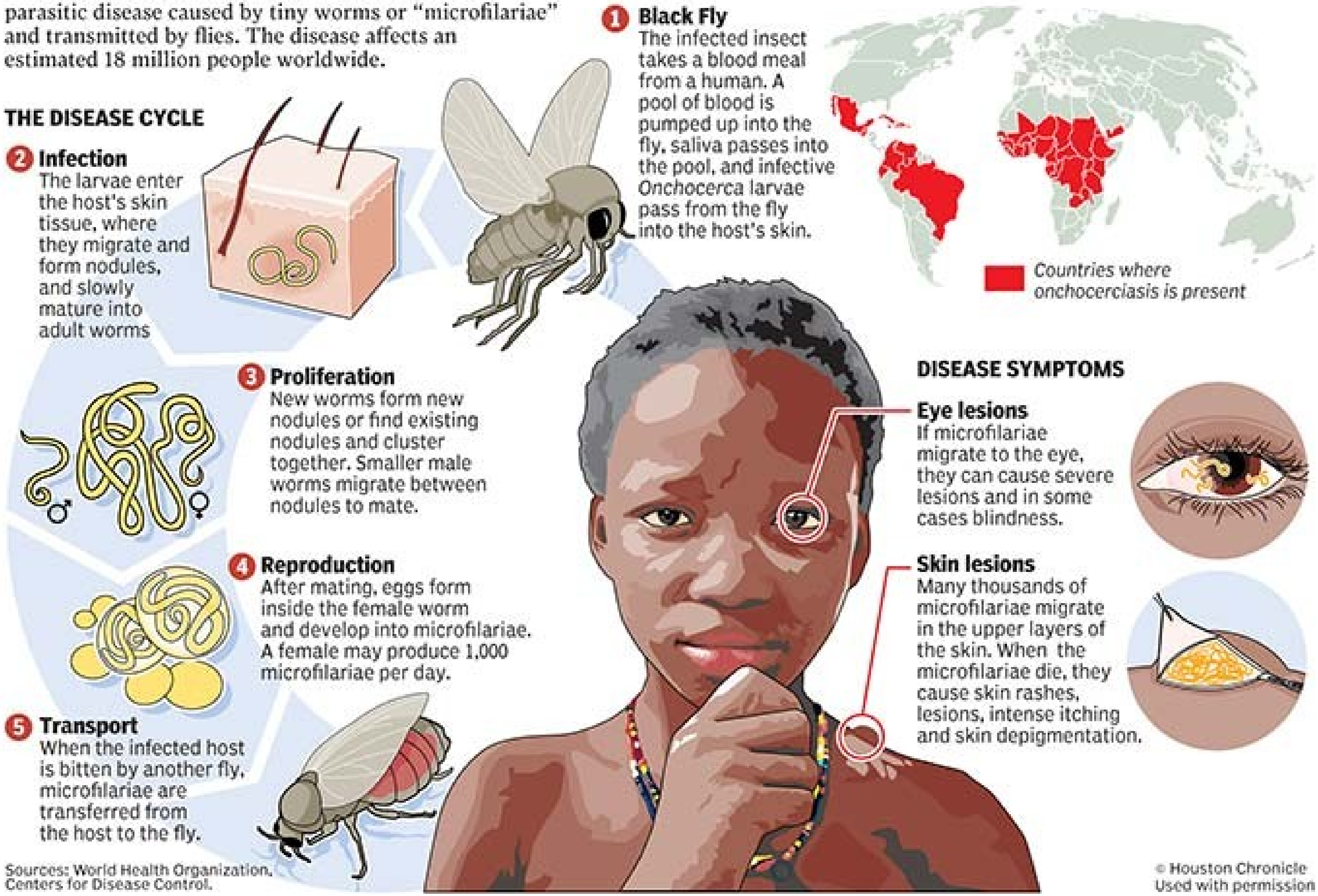
Onchocerciasis



New worms form new nodules or find existing nodules and cluster together

RIVER BLINDNESS

Onchocerciasis, also known as river blindness, is a parasitic disease caused by tiny worms or "microfilariae" and transmitted by flies. The disease affects an estimated 18 million people worldwide.



THE DISEASE CYCLE

① Black Fly
The infected insect takes a blood meal from a human. A pool of blood is pumped up into the fly, saliva passes into the pool, and infective *Onchocerca* larvae pass from the fly into the host's skin.

② Infection
The larvae enter the host's skin tissue, where they migrate and form nodules, and slowly mature into adult worms

③ Proliferation
New worms form new nodules or find existing nodules and cluster together. Smaller male worms migrate between nodules to mate.

④ Reproduction
After mating, eggs form inside the female worm and develop into microfilariae. A female may produce 1,000 microfilariae per day.

⑤ Transport
When the infected host is bitten by another fly, microfilariae are transferred from the host to the fly.

World distribution

🟥 *Countries where onchocerciasis is present*

DISEASE SYMPTOMS

Eye lesions
If microfilariae migrate to the eye, they can cause severe lesions and in some cases blindness.

Skin lesions
Many thousands of microfilariae migrate in the upper layers of the skin. When the microfilariae die, they cause skin rashes, lesions, intense itching and skin depigmentation.

Sources: World Health Organization, Centers for Disease Control.

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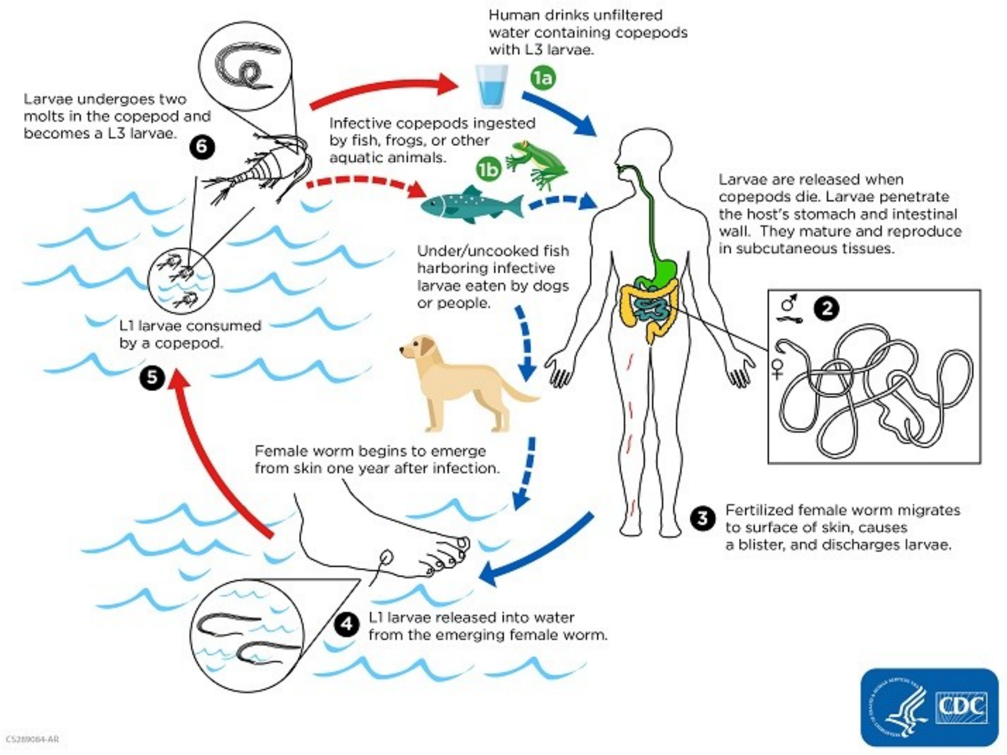
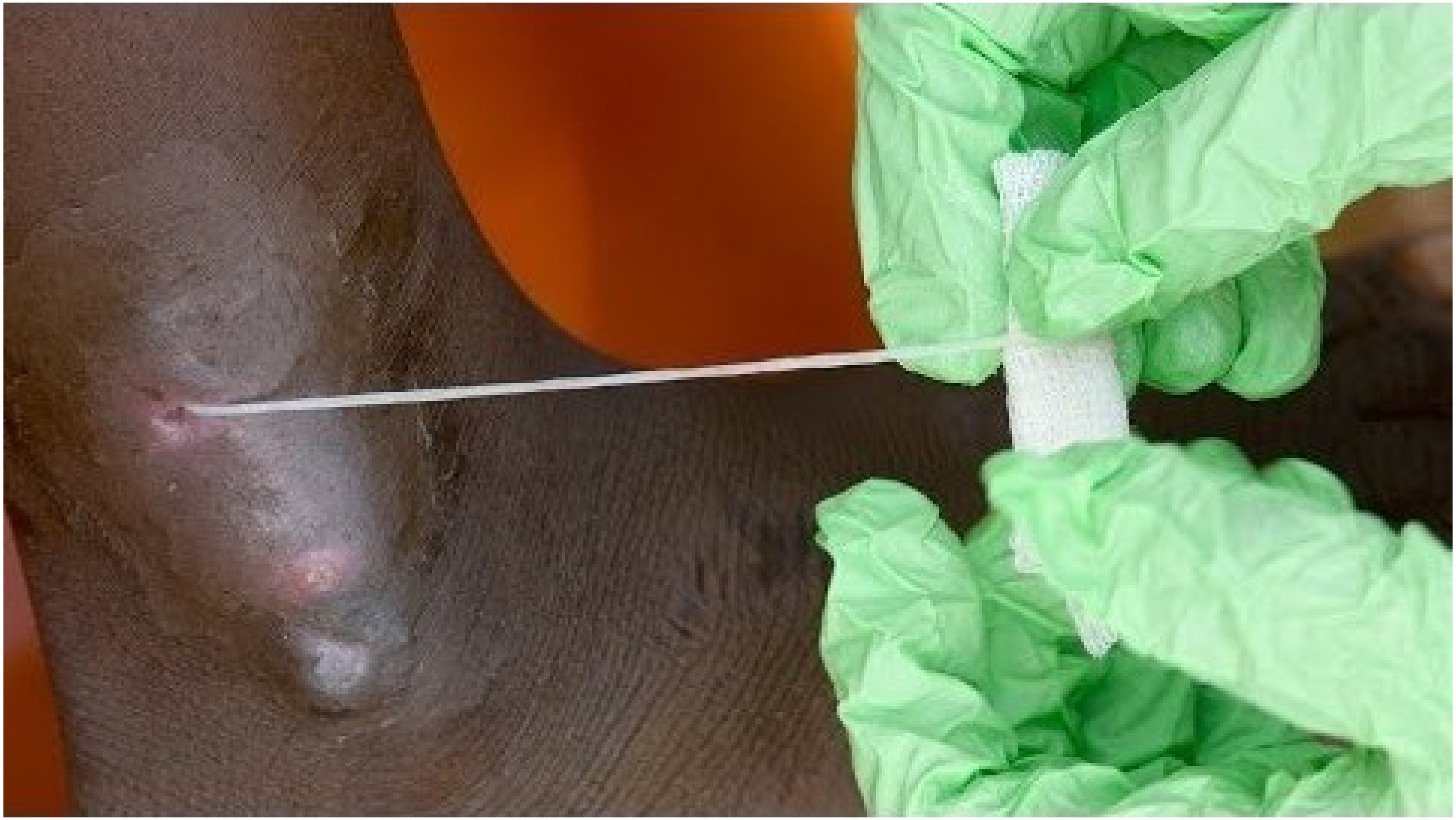
Guinea worm

- Dracunculiasis – infection with guinea worm, or guinea worm disease. Intermediate host is a crustacean copepod.


Human drinks unfiltered water containing copepods with L3 larvae.
1a
Infective copepods ingested by fish, frogs, or other aquatic animals.
1b
Under/uncooked fish harboring infective larvae eaten by dogs or people.
Larvae are released when copepods die. Larvae penetrate the host's stomach and intestinal wall. They mature and reproduce in subcutaneous tissues.
♂
2
♀
3
Fertilized female worm migrates to surface of skin, causes a blister, and discharges larvae.
4
L1 larvae released into water from the emerging female worm.
Female worm begins to emerge from skin one year after infection.
5
L1 larvae consumed by a copepod.
6
Larvae undergoes two molts in the copepod and becomes a L3 larvae.
CS289084-AR
CDC

Guinea worm disease-*Dracunculus medinensis*



More Nematode Parasites

- *Dog heartworm, Dirofilaria immitis*, is carried by mosquitoes and is the most common U.S. filarial worm
- Give dogs and cats heartworm pills to stop infection

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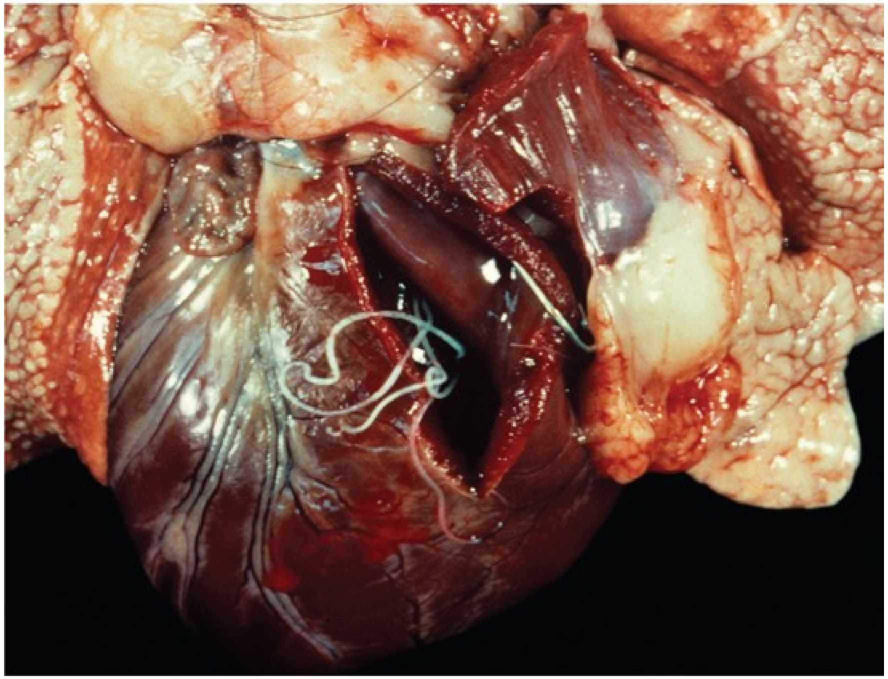

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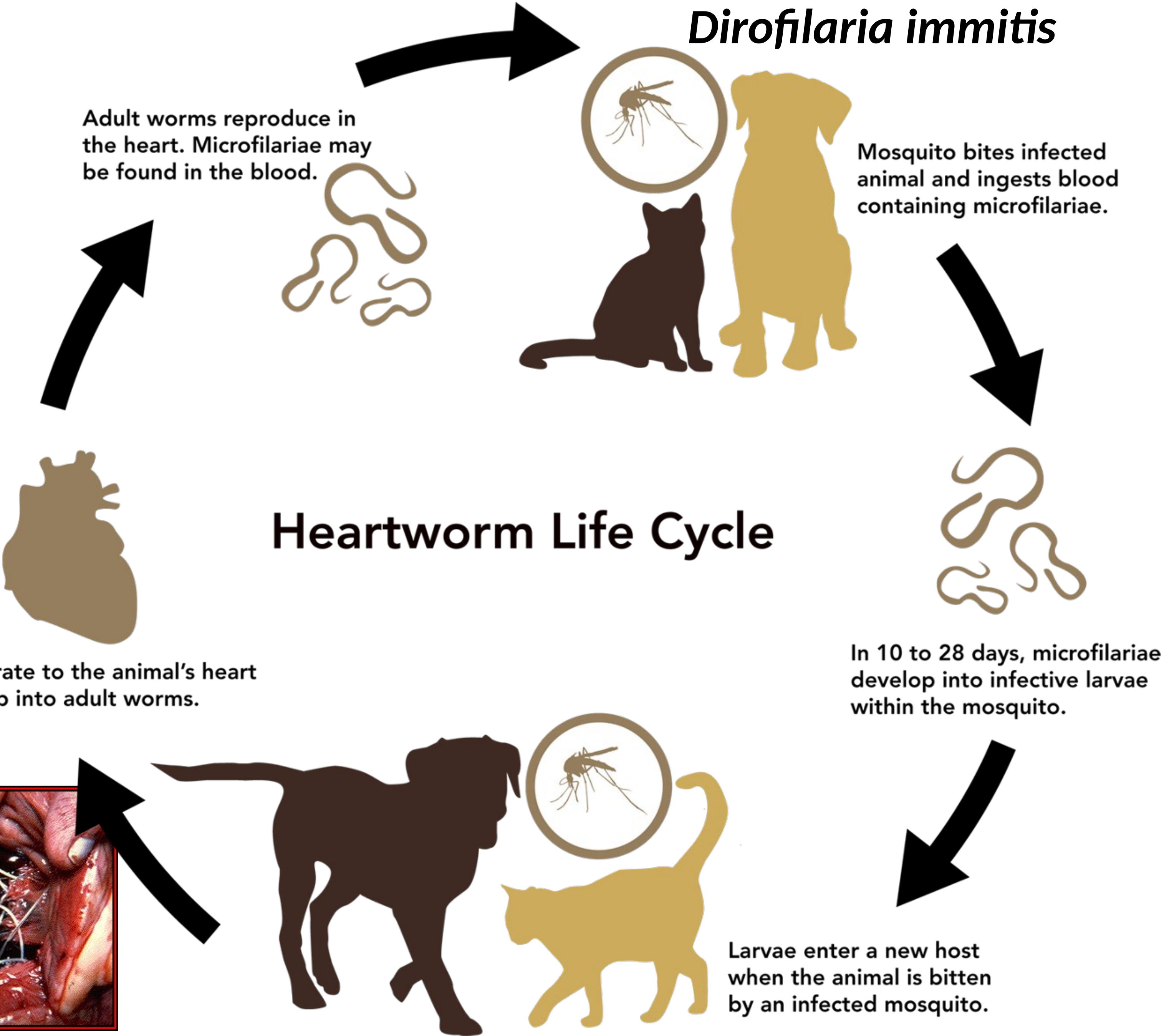
Dirofilaria immitis



Heartworm Life Cycle

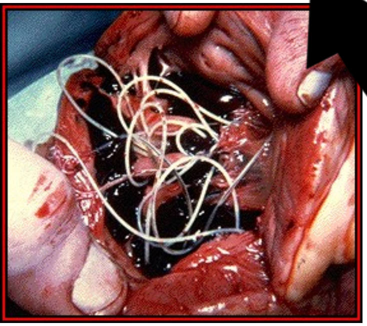
Mosquito bites infected animal and ingests blood containing microfilariae.

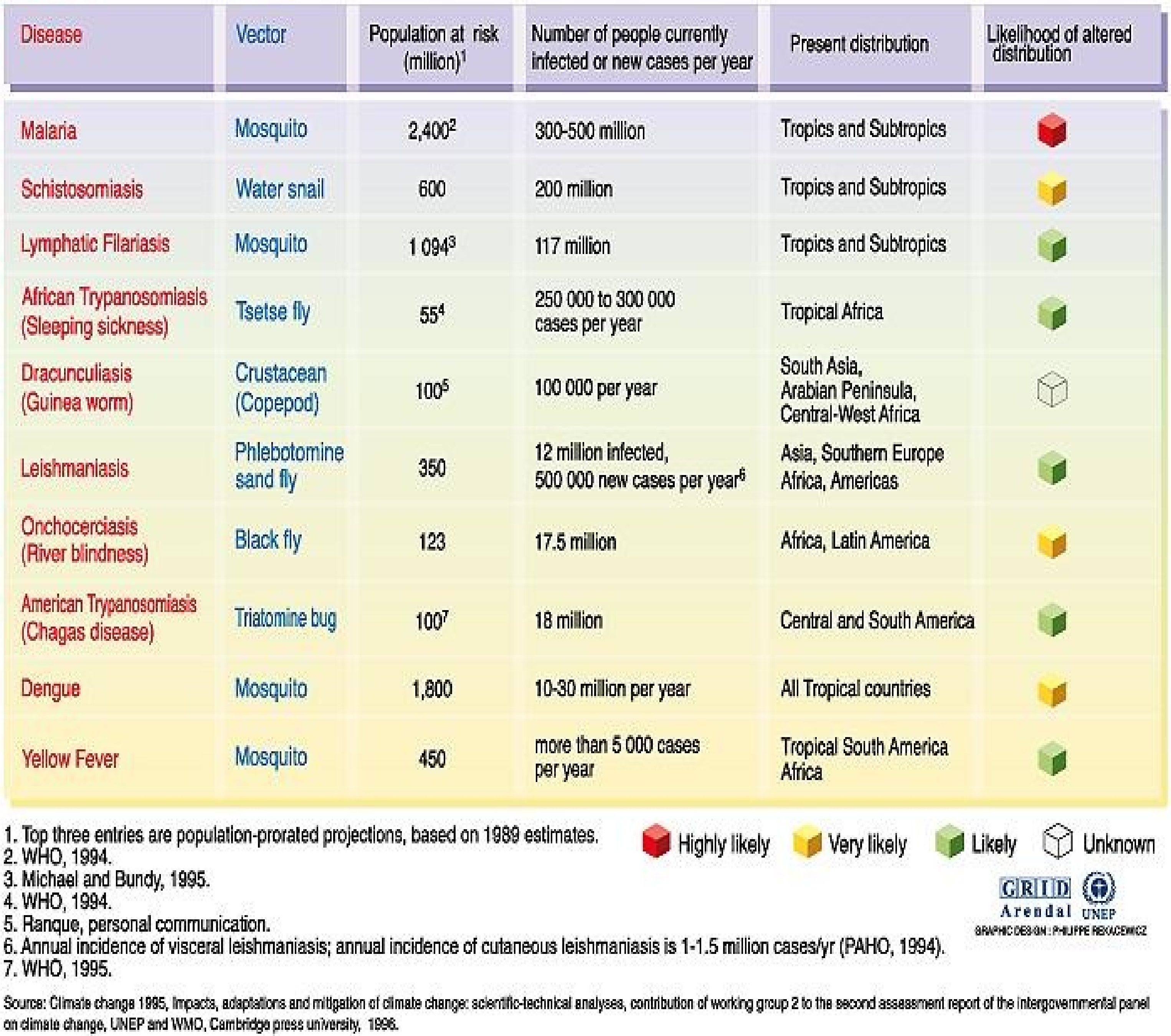
In 10 to 28 days, microfilariae develop into infective larvae within the mosquito.

Larvae enter a new host when the animal is bitten by an infected mosquito.

Larvae migrate to the animal's heart and develop into adult worms.

Adult worms reproduce in the heart. Microfilariae may be found in the blood.





Disease	Vector	Population at risk (million)[1]	Number of people currently infected or new cases per year	Present distribution	Likelihood of altered distribution
Malaria	Mosquito	2,400[2]	300-500 million	Tropics and Subtropics	🟥
Schistosomiasis	Water snail	600	200 million	Tropics and Subtropics	🟨
Lymphatic Filariasis	Mosquito	1 094[3]	117 million	Tropics and Subtropics	🟩
African Trypanosomiasis (Sleeping sickness)	Tsetse fly	55[4]	250 000 to 300 000 cases per year	Tropical Africa	🟩
Dracunculiasis (Guinea worm)	Crustacean (Copepod)	100[5]	100 000 per year	South Asia, Arabian Peninsula, Central-West Africa	☐
Leishmaniasis	Phlebotomine sand fly	350	12 million infected, 500 000 new cases per year[6]	Asia, Southern Europe Africa, Americas	🟩
Onchocerciasis (River blindness)	Black fly	123	17.5 million	Africa, Latin America	🟨
American Trypanosomiasis (Chagas disease)	Triatomine bug	100[7]	18 million	Central and South America	🟩
Dengue	Mosquito	1,800	10-30 million per year	All Tropical countries	🟨
Yellow Fever	Mosquito	450	more than 5 000 cases per year	Tropical South America Africa	🟩

🟥 Highly likely 🟨 Very likely 🟩 Likely ☐ Unknown

1. Top three entries are population-prorated projections, based on 1989 estimates.
2. WHO, 1994.
3. Michael and Bundy, 1995.
4. WHO, 1994.
5. Ranque, personal communication.
6. Annual incidence of visceral leishmaniasis; annual incidence of cutaneous leishmaniasis is 1-1.5 million cases/yr (PAHO, 1994).
7. WHO, 1995.

GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source: Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Protozoan

Trematode

Nematode

Protozoan

Nematode

Protozoan

Nematode

Protozoan

Virus

Virus

PHYLUM ARTHROPODA – JOINT LEGGED ANIMALS

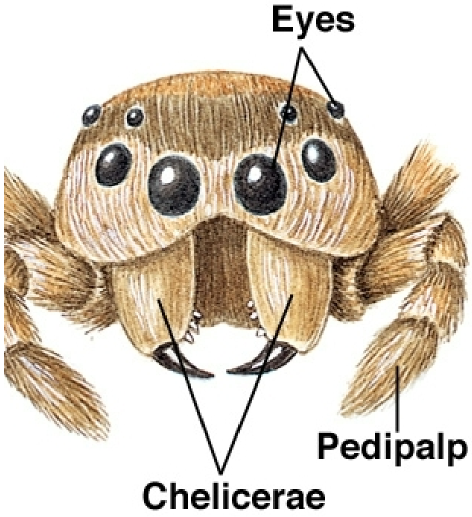
Number of species identified: > 1,000,000.

Largest animal phylum: consider that there are ~ 1.4 million named species of ALL organisms (and >250,000 of those are plants).

Arthropods are the most dominant phylum on earth, and have enormous ecological and economic importance. They are found everywhere.

Success related to **body plan** that permits them to live in all major biomes

- Versatile exoskeleton
- Segmentation and jointed appendages for more efficient locomotion
- Highly developed sensory organs
- Complex behavior patterns



CHARACTERISTICS

- External “Metamerism” (segments) and tagmatization (grouping the segments)
- EXOSKELETON of chiton (polysaccharide) – ECDYSIS (molting)
- Paired jointed appendages
- Open circulatory system with HEMOCOEL (with hemolymph)
- Respiration –Gills, Tracheae, or Book lungs
- Excretory: paired glands or multiple Malpighian tubules
- Ventral nerve cord, well developed sensory organs
- Dioecious, internal fertilization, METAMORPHOSIS

THE EXOSKELETON

Exoskeleton (cuticle)

- External, jointed skeleton

Functions

- Structural support
- Protection
- Prevents water loss

System of levers for muscle attachment and movement

Covers all body surfaces and invaginations of the body wall

Nonliving, secreted by epidermis

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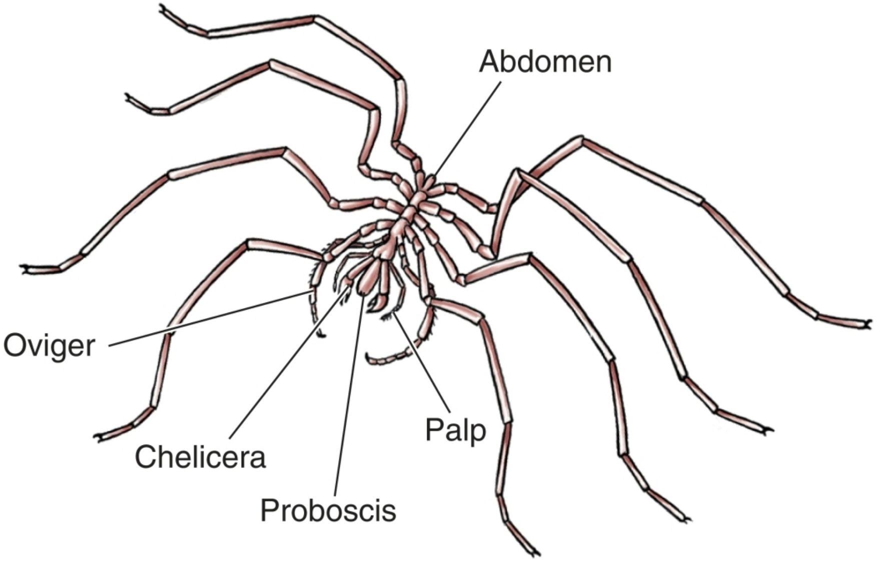


PHYLUM ARTHROPODA

Ecdysis

- Molting occurs often in young animals and may cease in adults
- Necessary for a crustacean to increase in size the
    - Exoskeleton does not grow
- Underlying *epidermis* secretes cuticle
- contains protein, calcium salts, and chitin

PHYLUM ARTHROPODA

- During premolt the old cuticle becomes thinner as inorganic salts are withdrawn from it and stored in tissue
- Underlying epidermis begins to grow by cell division: Secretes a *new cuticle*
- *Enzymes* released into the area above new cuticle dissolve the *old cuticle*
- The animal then swells with water or air to expand and *burst the old cuticle*
- Postmolt stage soft new cuticle stretches and then hardens with the deposition of inorganic salts

Molt 1

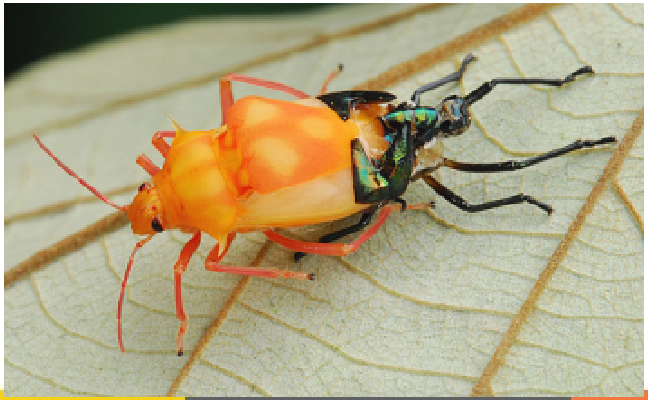
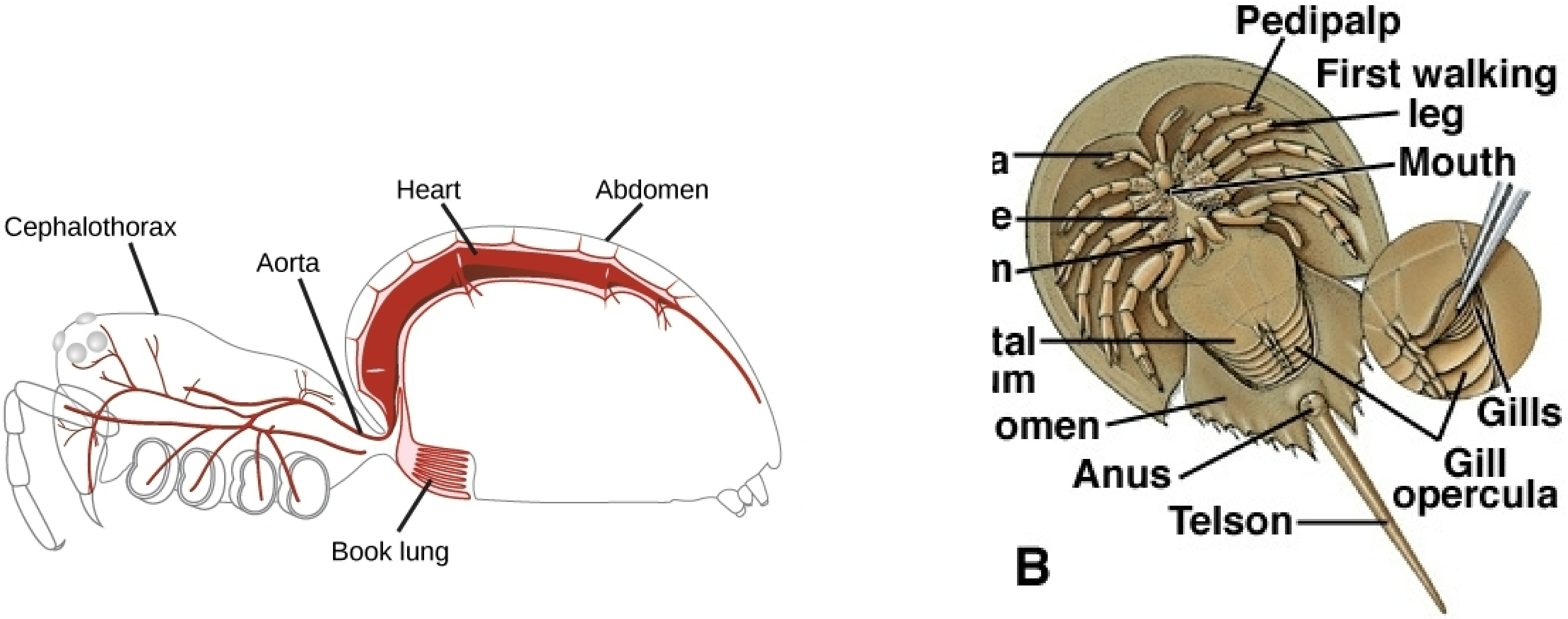


FIGURE 15.19



(a)

The book lungs of (a) arachnids are made up of alternating air pockets and hemocoel tissue shaped like a stack of books. The book gills of (b) crustaceans are similar to book lungs but are external so that gas exchange can occur with the surrounding water. (credit a: modification of work by Ryan Wilson based on original work by John Henry Comstock; credit b: modification of work by Angel Schatz)

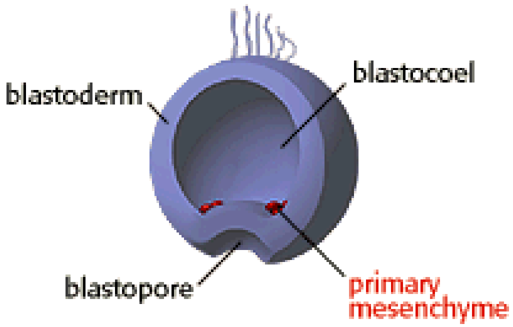
THE HEMOCOEL

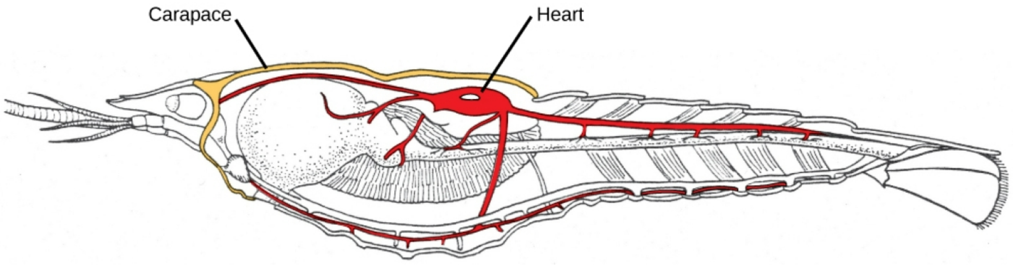
Arthropod hemocoel from embryonic blastocoel

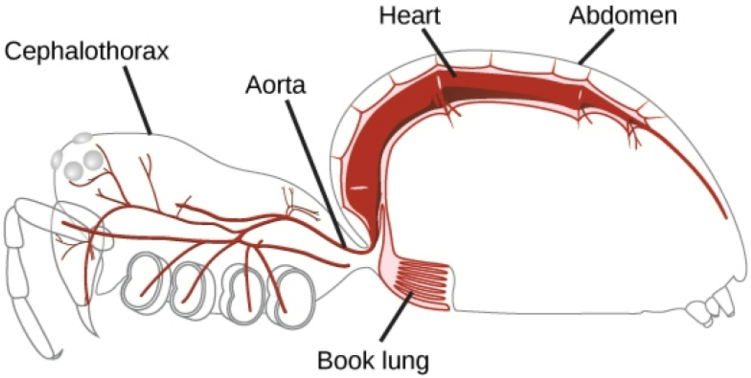
Internal cavity for open circulatory system

- Hemolymph fluids bathe internal organs
- Exchange of nutrients, wastes, and sometimes gases

Not a hydrostatic compartment



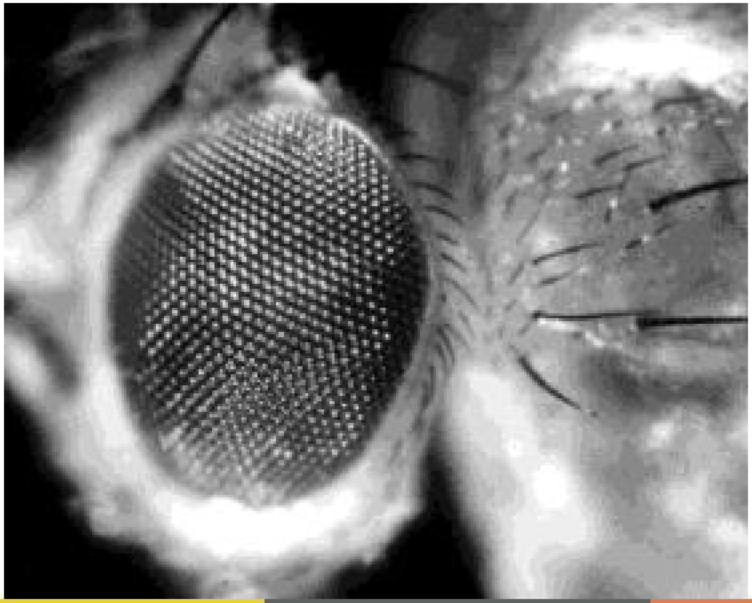




(a)

EYES

- Compound eyes, made of many units called *ommatidia*
- Can adapt to bright or dim light
- Small crustaceans 2-12 ommatidia to 15,000 in lobster
- Spiders and Myriapoda have only simple eyes



Subphyla of Arthropods

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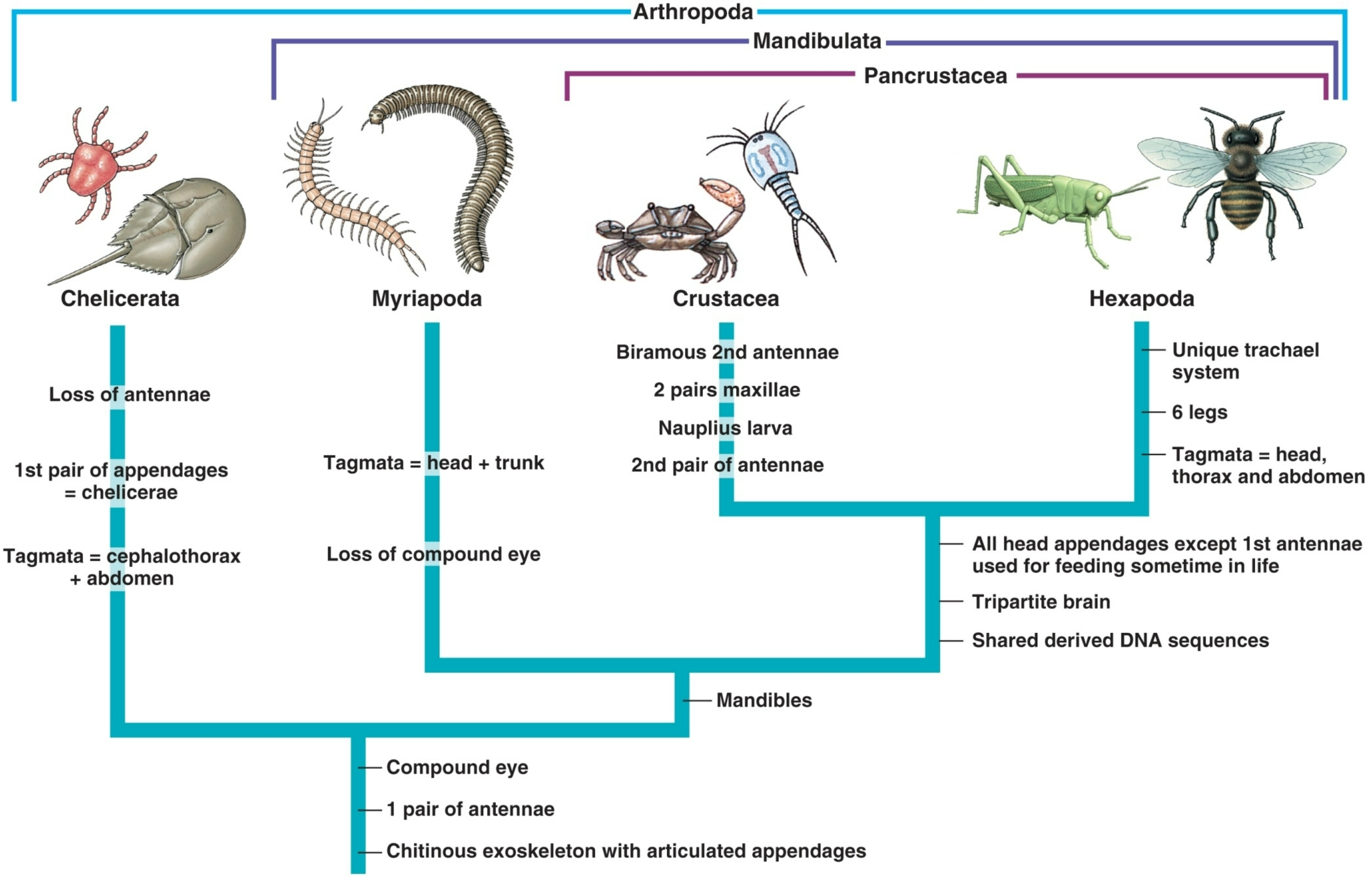


Arthropoda

Mandibulata

Pancrustacea

Chelicerata

Myriapoda

Crustacea

Hexapoda

Chelicerata:
- Loss of antennae
- 1st pair of appendages = chelicerae
- Tagmata = cephalothorax + abdomen

Myriapoda:
- Tagmata = head + trunk
- Loss of compound eye

Crustacea:
- Biramous 2nd antennae
- 2 pairs maxillae
- Nauplius larva
- 2nd pair of antennae

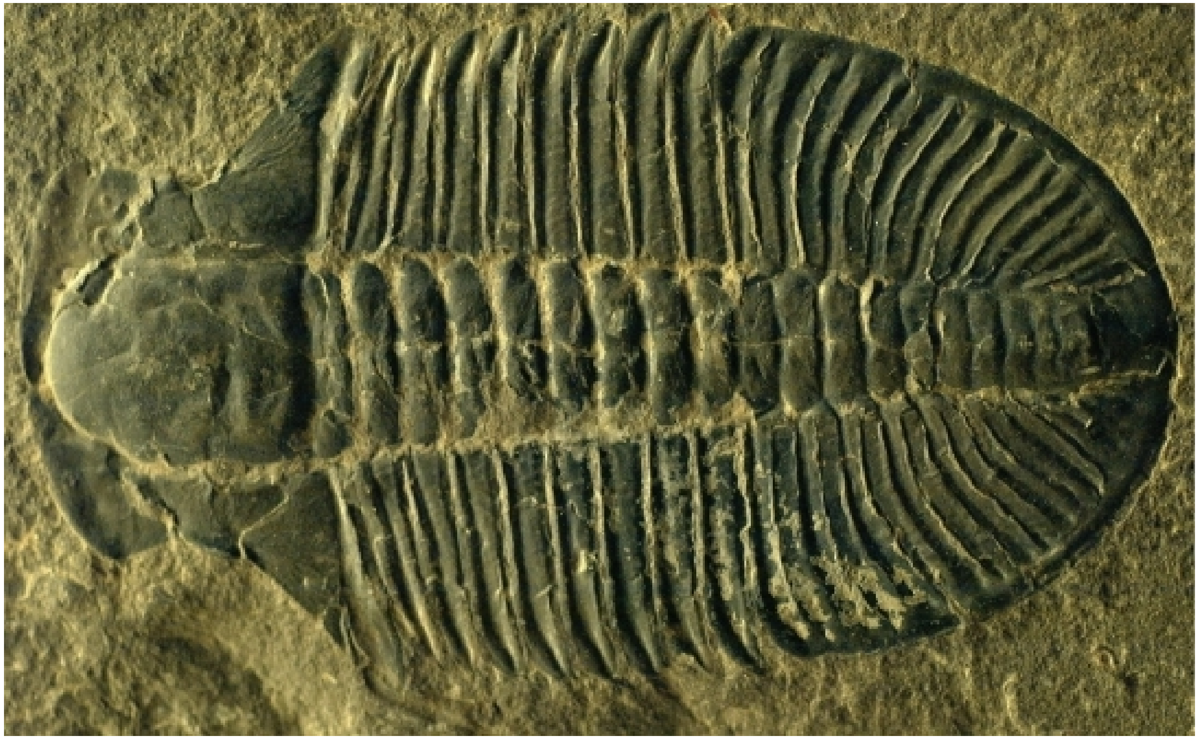
Hexapoda:
- Unique trachael system
- 6 legs
- Tagmata = head, thorax and abdomen

Pancrustacea:
- All head appendages except 1st antennae used for feeding sometime in life
- Tripartite brain
- Shared derived DNA sequences

Mandibulata:
- Mandibles

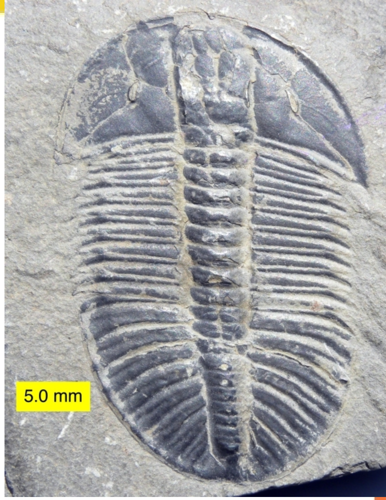
Arthropoda:
- Compound eye
- 1 pair of antennae
- Chitinous exoskeleton with articulated appendages

FIGURE 15.18



Trilobites, like the one in this fossil, are an extinct group of arthropods. (credit: Kevin Walsh)

TRILOBITES



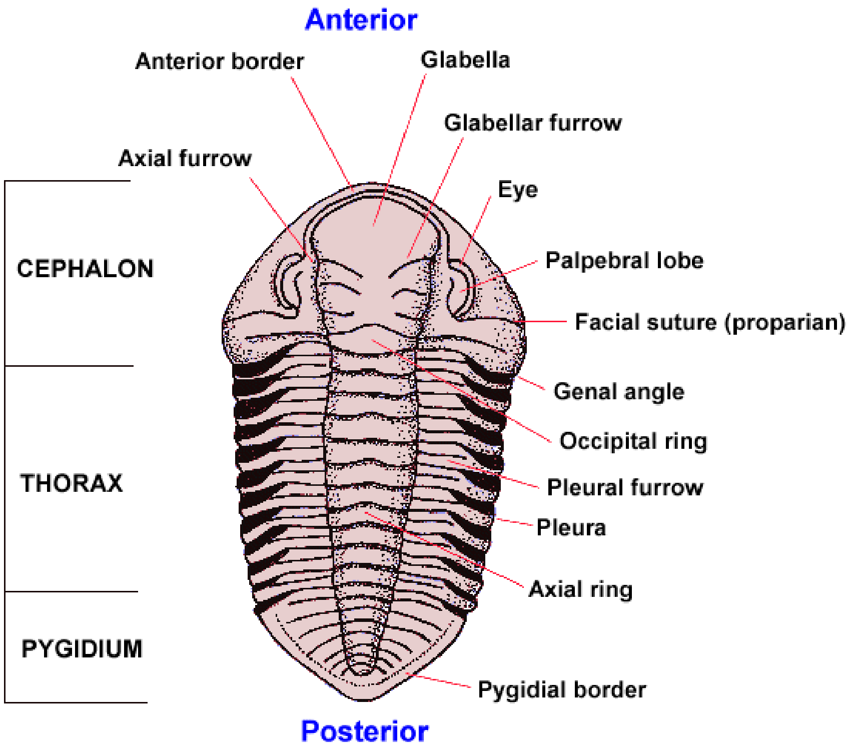
Extinct for 250 million years

Abundant 600mya

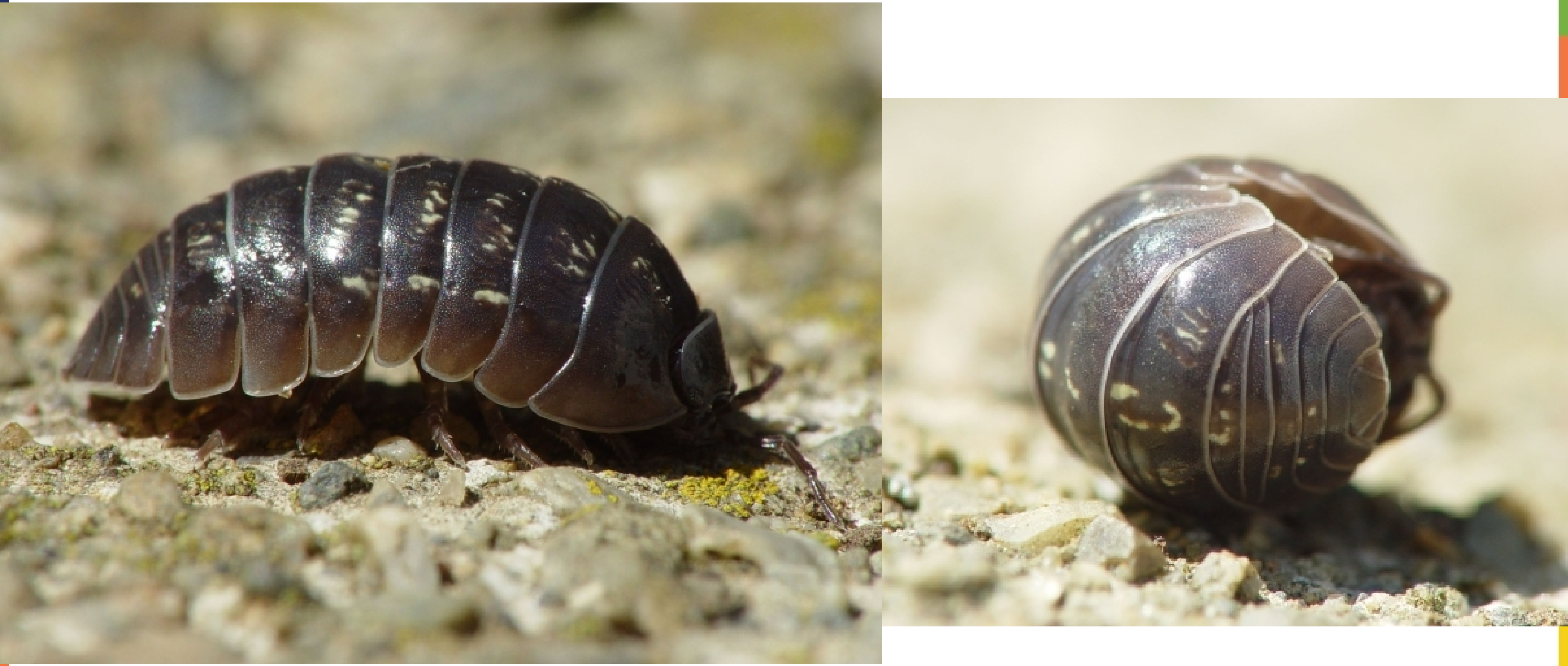
Tri-lobed shaped body, pair of longitudinal grooves

All body segments articulated so they could roll up into a ball & protect the soft ventral surface

Probably bottom dwellers and scavengers

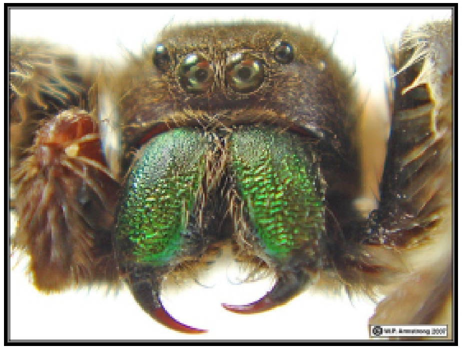

Anterior
Anterior border
Glabella
Glabellar furrow
Axial furrow
Eye
Palpebral lobe
Facial suture (proparian)
Genal angle
Occipital ring
Pleural furrow
Pleura
Axial ring
Pygidial border
CEPHALON
THORAX
PYGIDIUM
Posterior

ISOPODS (CRUSTACEAN)



Convergent evolution – looks and rolls like a Trilobite.

1. SUBPHYLUM CHELICERATA



Ancient group

No mandibles or antennae

2 segments and six pairs of cephalothoracic appendages (on head and thorax)

- 1 pair of chelicerae (define the subphylum)
- 1 pair of pedipalps
- 4 pairs of walking legs

Spiders, ticks, mites, scorpions, horseshoe crabs, sea spiders

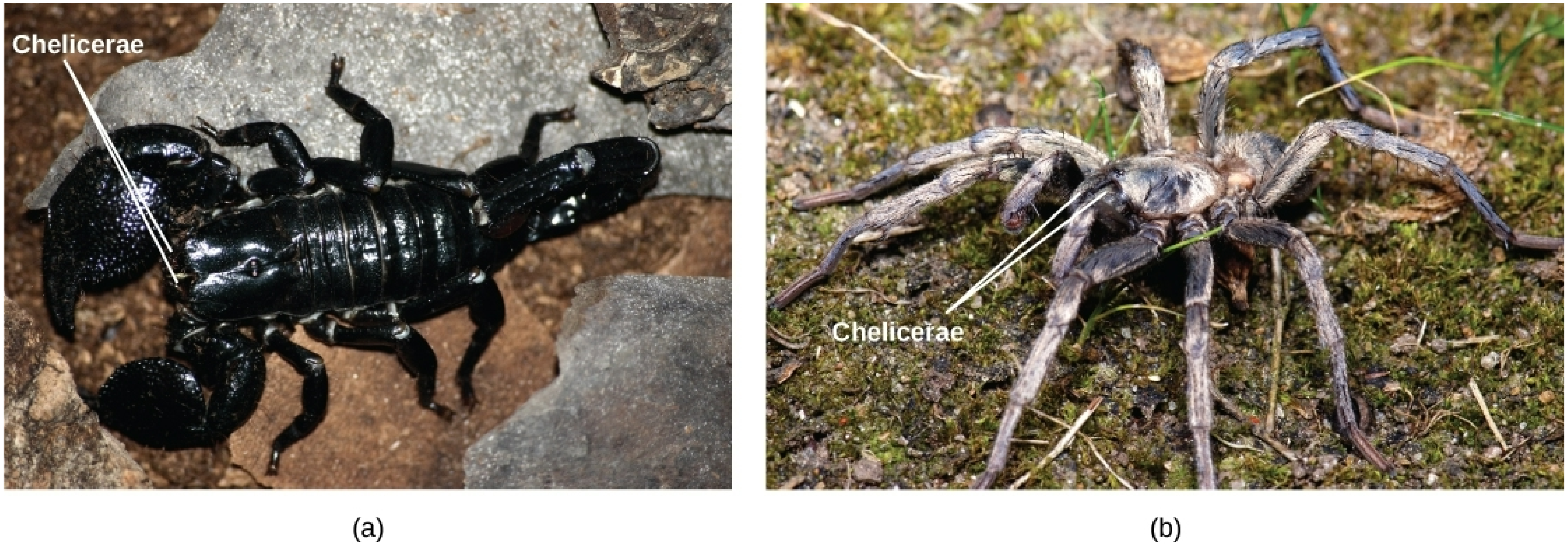
SUBPHYLUM CHELICERATA

Spiders, mites, ticks, horseshoe crabs, sea spiders

Two body regions

- Cephalothorax = “head-thorax” (prosoma)
  - Eyes
  - **Chelicerae (“fangs”)**
    - Often pincer-like
    - Usually feeding appendages
  - **Pedipalps**
    - Sensory, feeding, locomotion, reproduction
  - Walking legs
- Abdomen (Opisthosoma)
  - Contains digestive, reproductive, excretory, and respiratory organs

FIGURE 15.23



The chelicerae (first set of appendages) are well developed in the Chelicerata, which includes scorpions (a) and spiders (b). (credit a: modification of work by Kevin Walsh; credit b: modification of work by Marshal Hedin)

A. CLASS MEROSTOMATA

- Horseshoe crabs (5 species worldwide)
  - Book gills
    - Gas exchange between blood and water
  - Reproduction
    - Dioecious
    - External fertilization
  - Living fossil: 450mya

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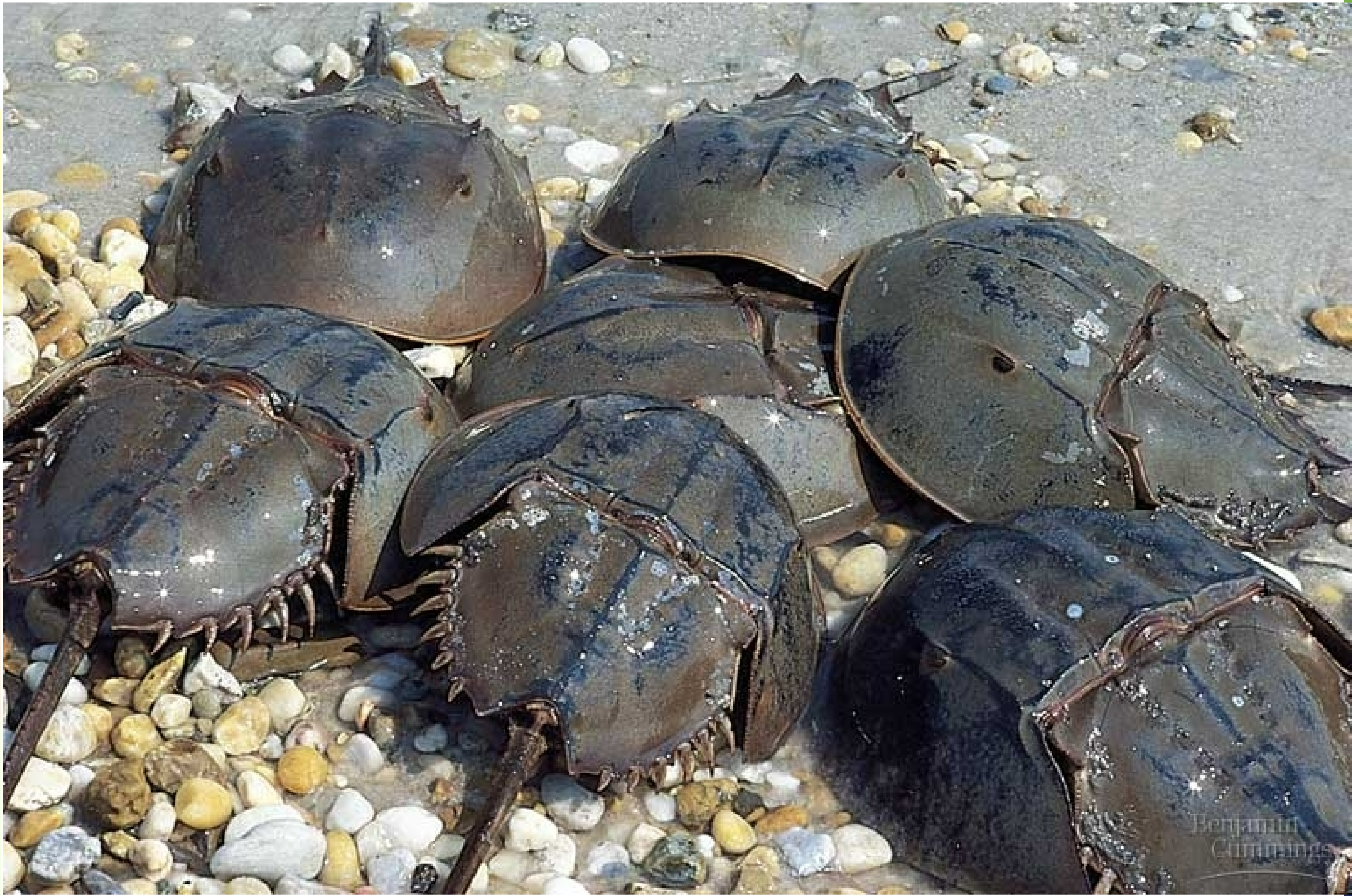
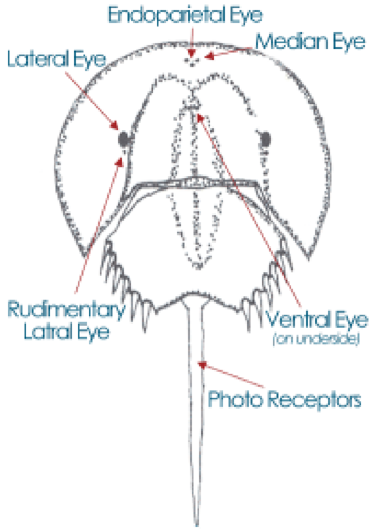
HORSESHOE CRABS, *LIMULUS POLYPHEMUS*



A horseshoe crab

Limulus sp.



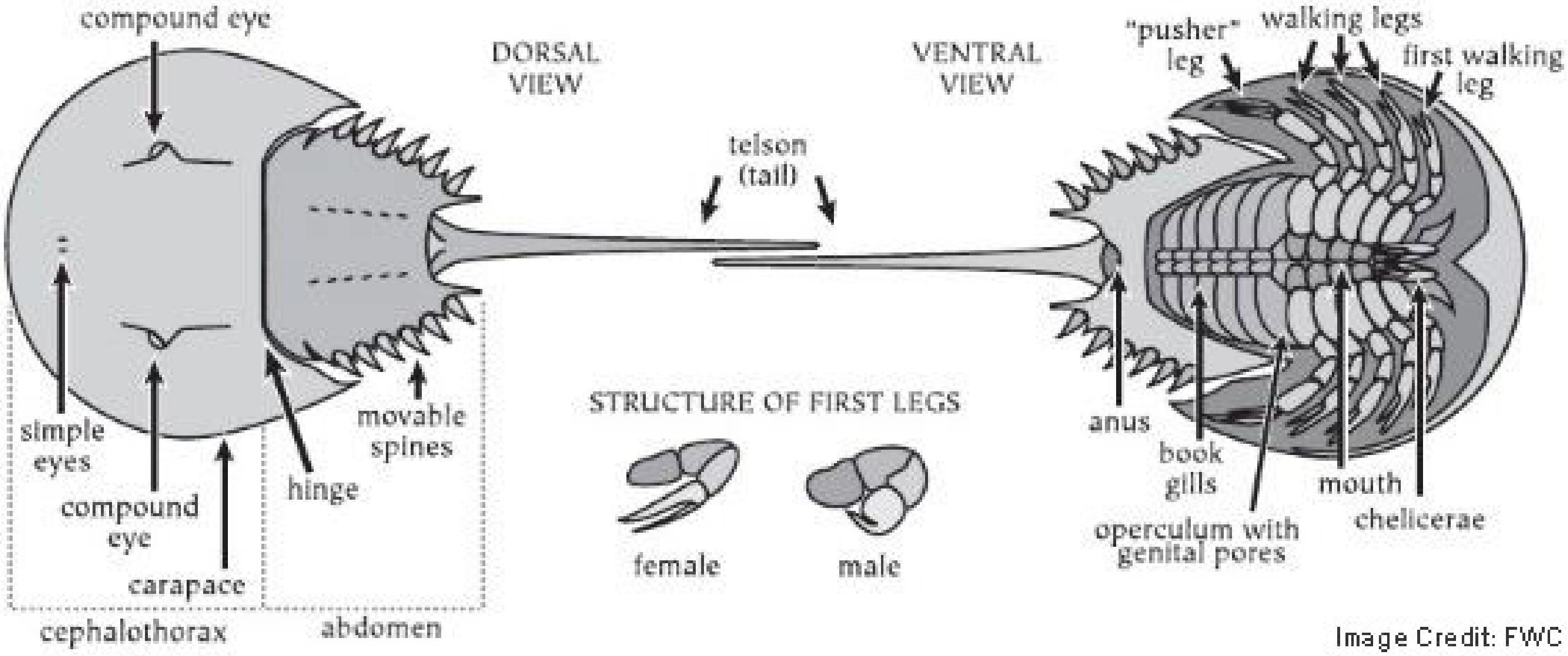
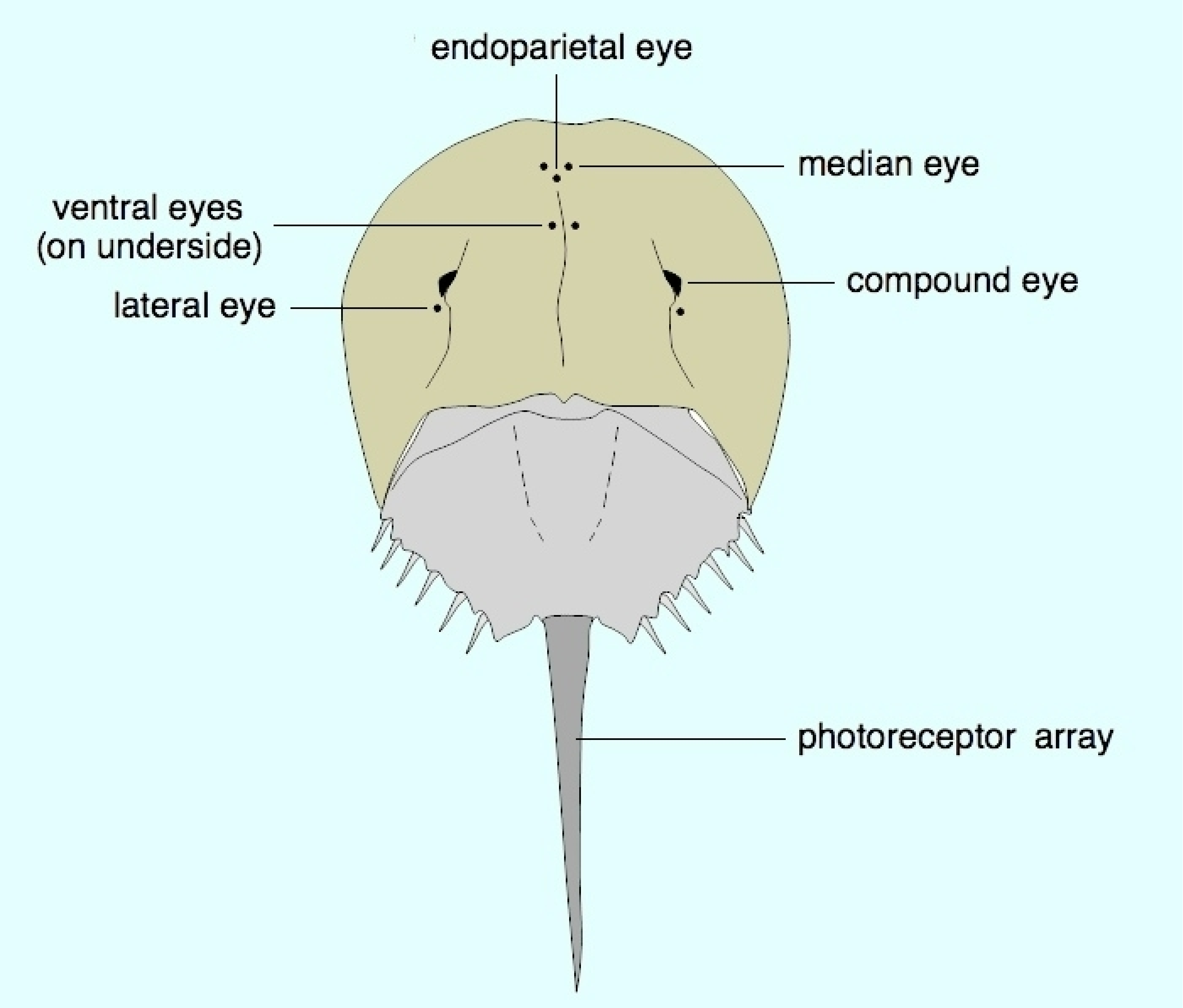
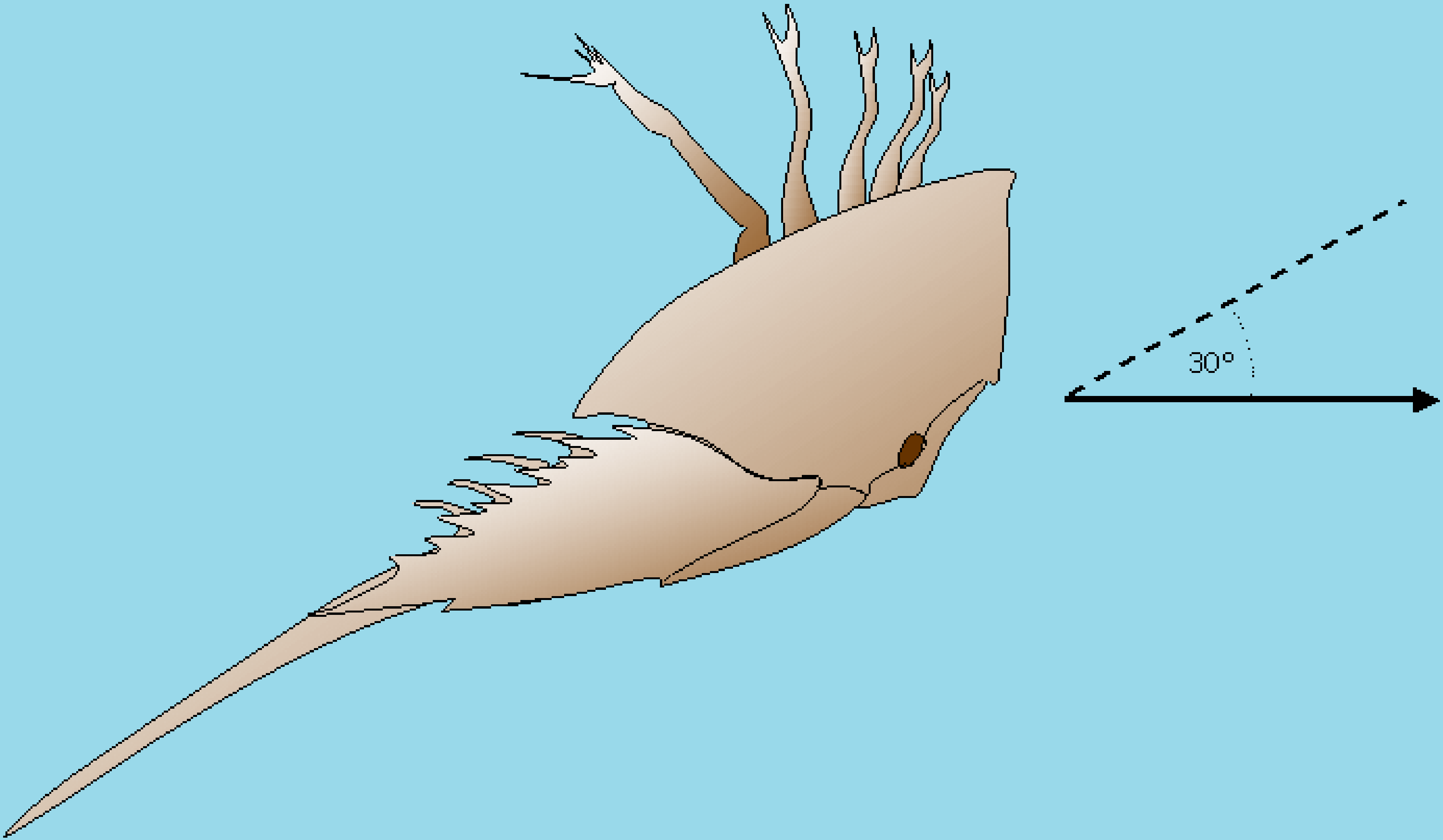


Image Credit: FWC


endoparietal eye
median eye
ventral eyes (on underside)
compound eye
lateral eye
photoreceptor array


30°

B. CLASS PYCNOGONIDA

Sea spiders

4 pairs of walking legs

Suctorial proboscis

Small abdomen

Males use ovigers (pair of legs) to carry egg masses

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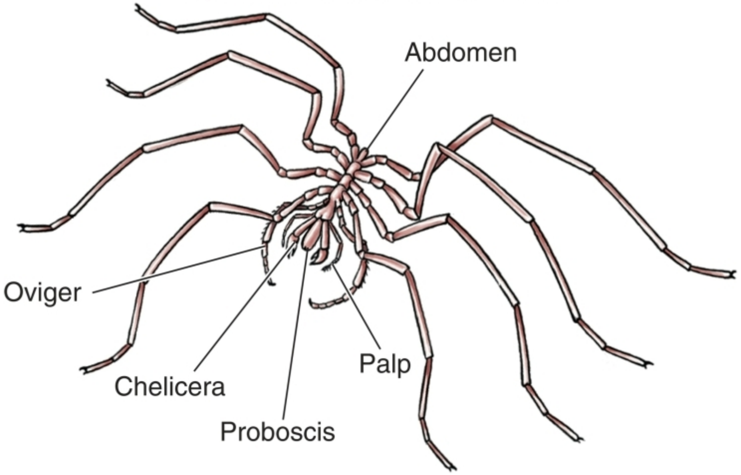
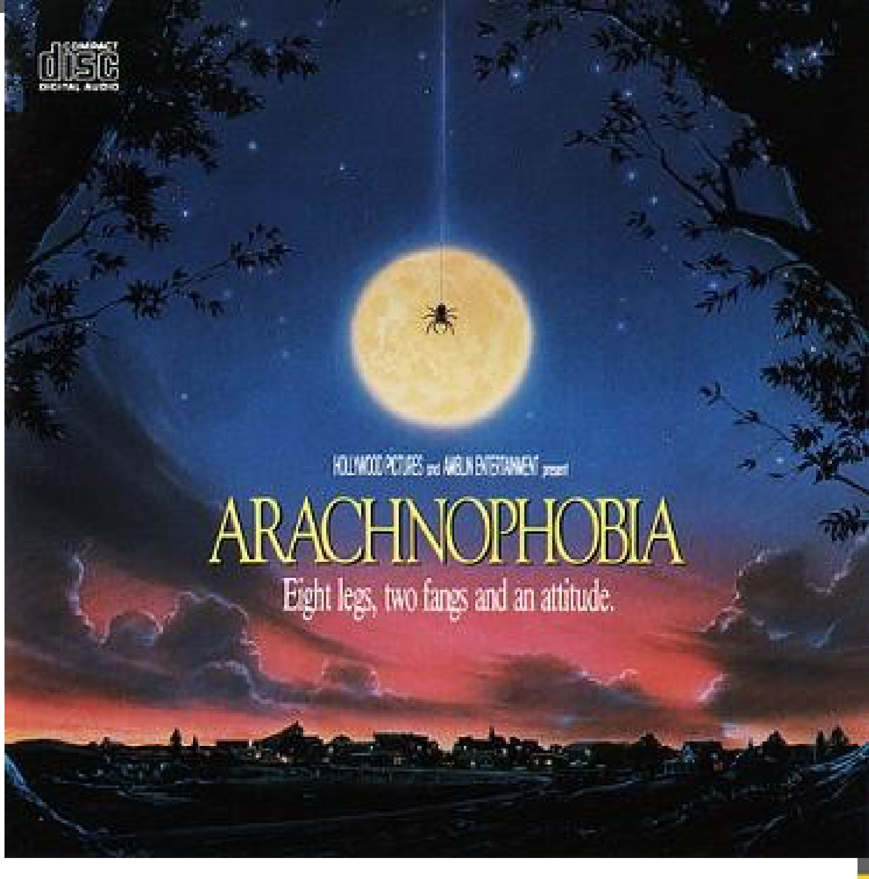


C. CLASS ARACHNIDA


HOLLYWOOD PICTURES and AMBLIN ENTERTAINMENT present
ARACHNOPHOBIA
Eight legs, two fangs and an attitude.

Over 80,000 species described

Spiders, scorpions, whip scorpions, pseudoscorpions, ticks, mites, harvestmen, etc.

Prosoma (cephalothorax) and Opisthosoma (abdomen)

Book lungs, tracheae or both

a. Order Araneae

b. Order Scorpionidae

c. Order Acari

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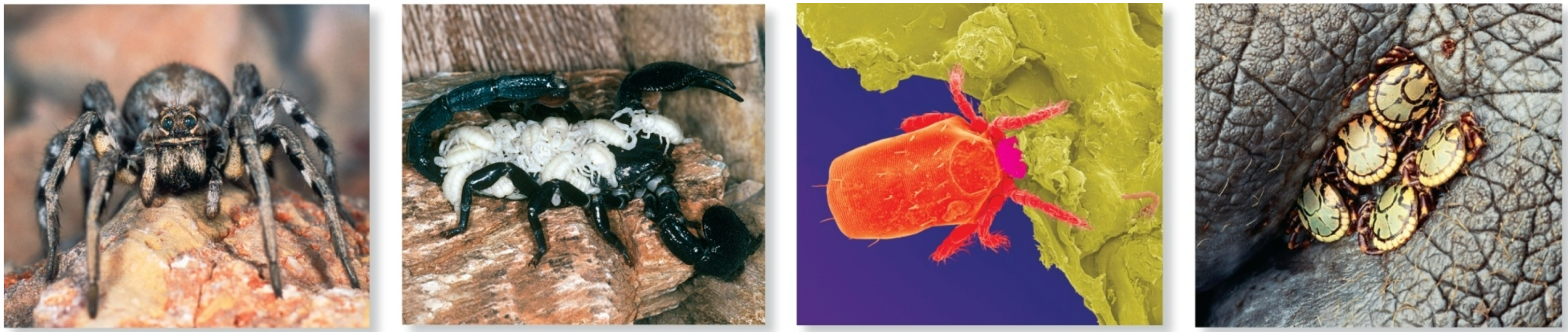

(a) Wolf spider **(b) Scorpion with young** **(c) Chigger mite** **(d) Bont ticks**

a: © Duncan Usher/ardea.com; b: © Paul Freed/Animals Animals;
c: © Dr. Dennis Kunkel Microscopy/Visuals Unlimited; d: © Roger De LaHarpe/Gallo Images/Corbis

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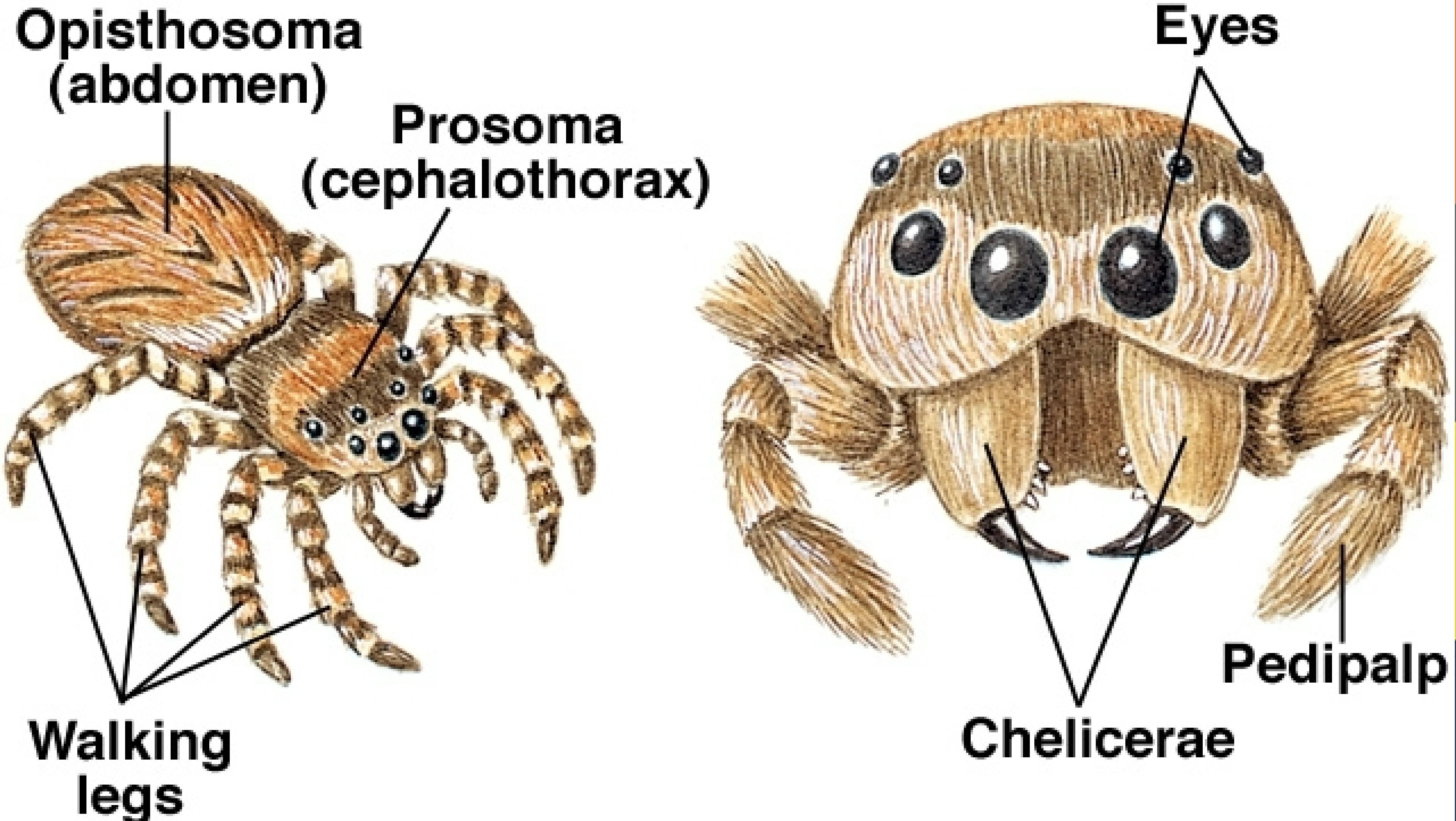
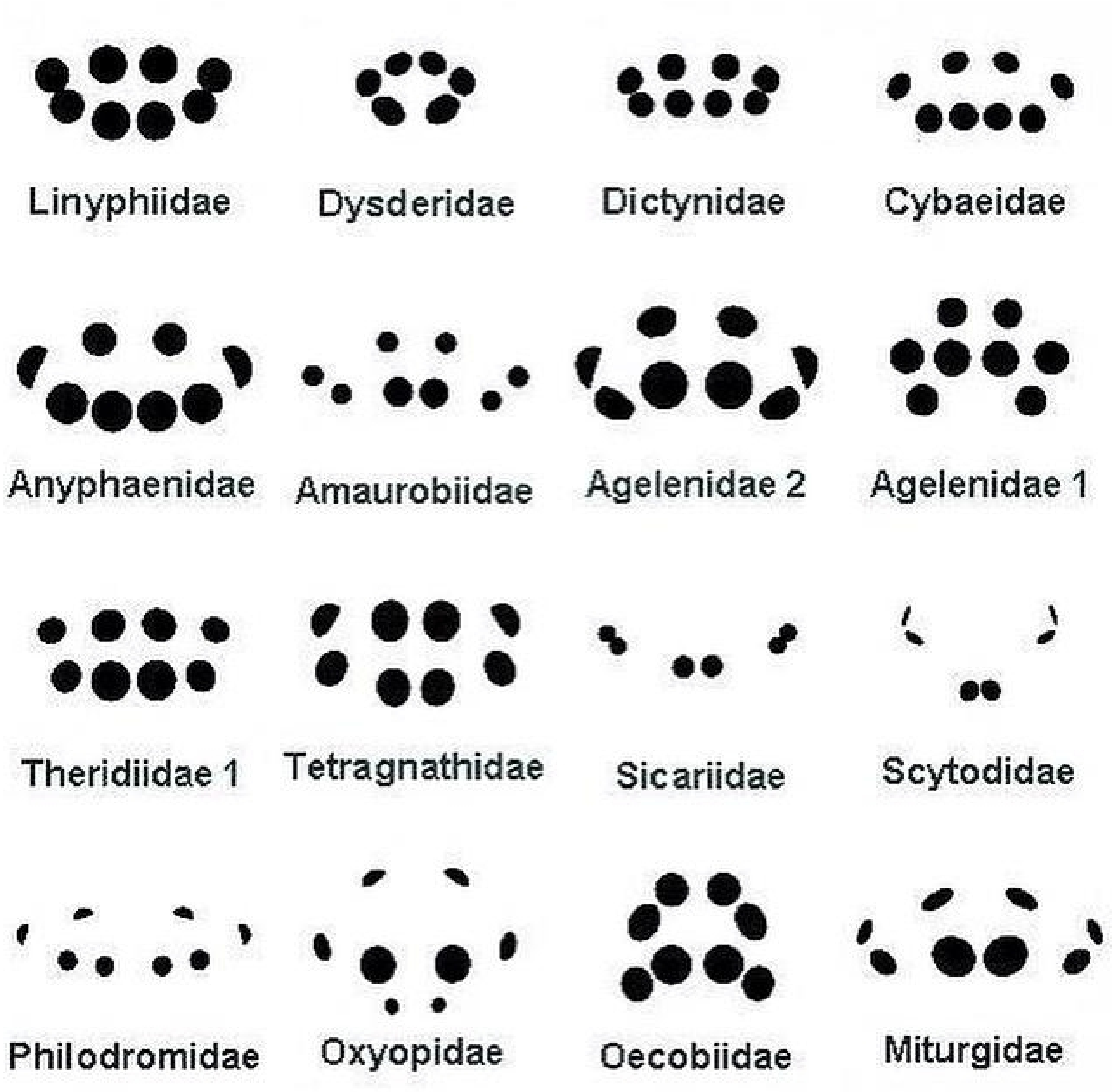
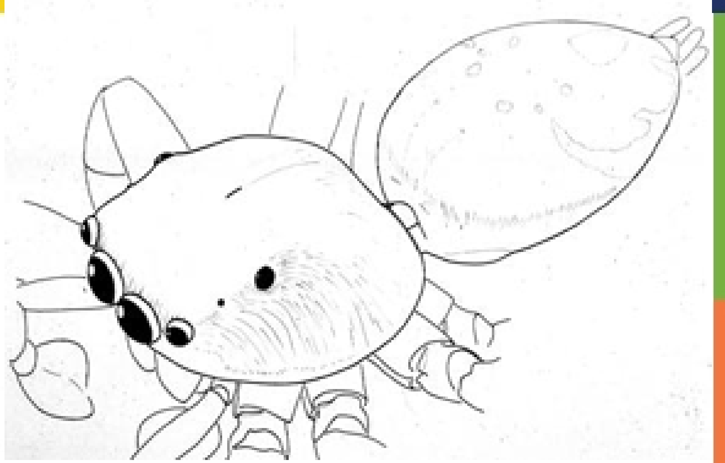
Anatomy of a jumping spider

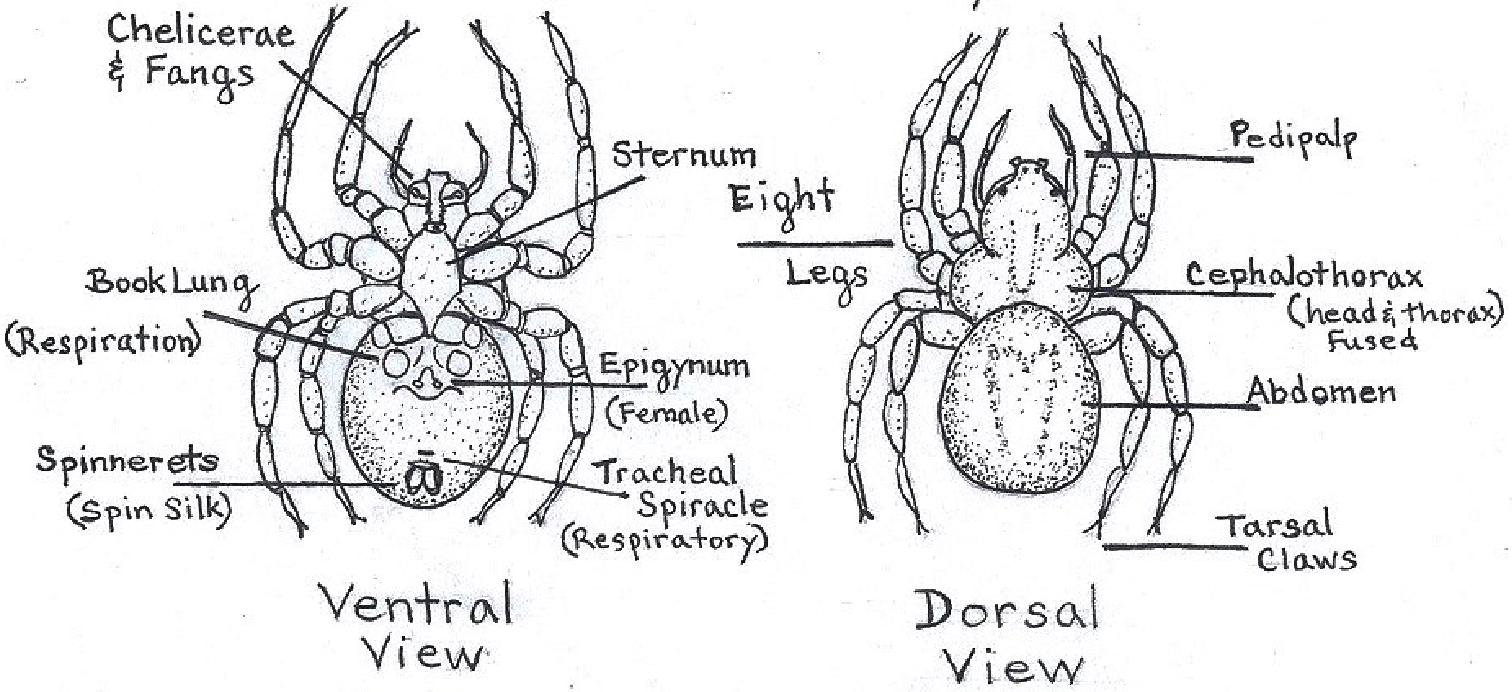


SPIDER SIMPLE EYE PATTERNS





Spider Anatomy



Donna Walker

SPIDER ANATOMY

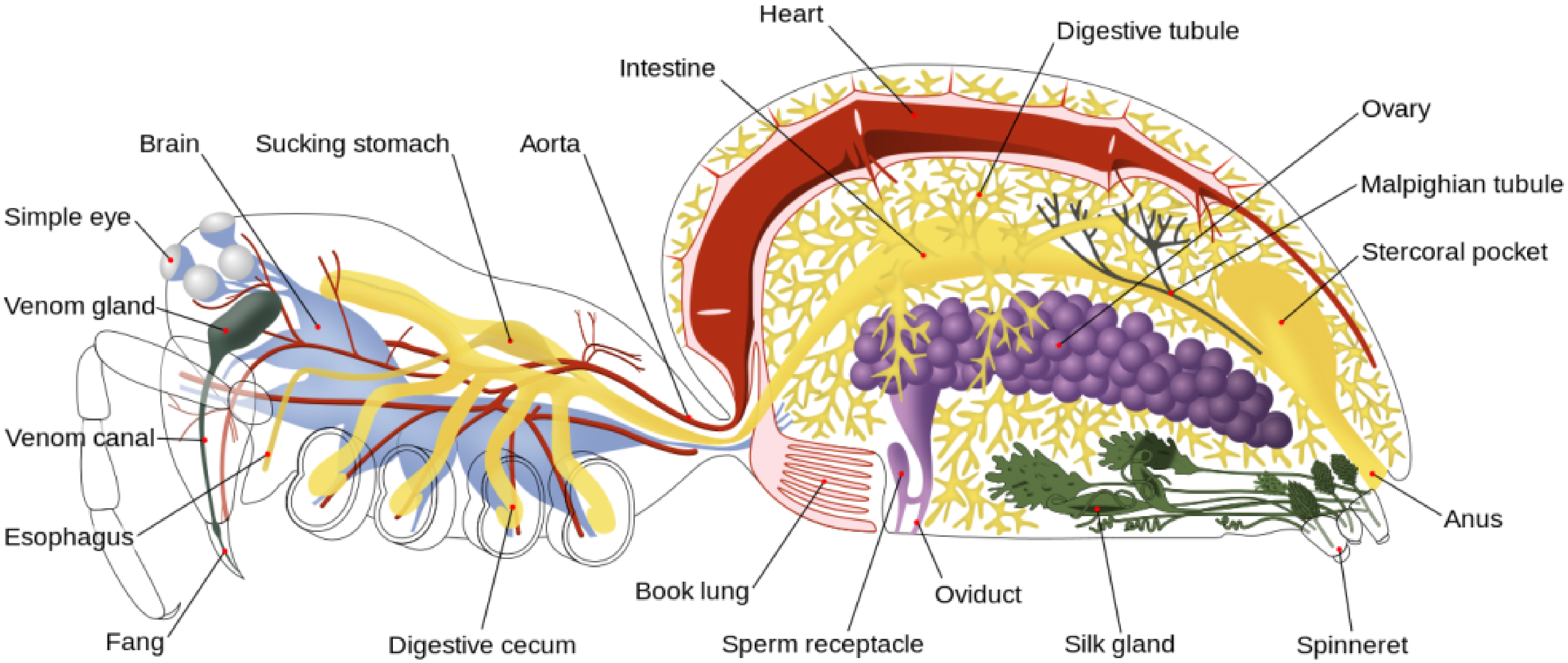
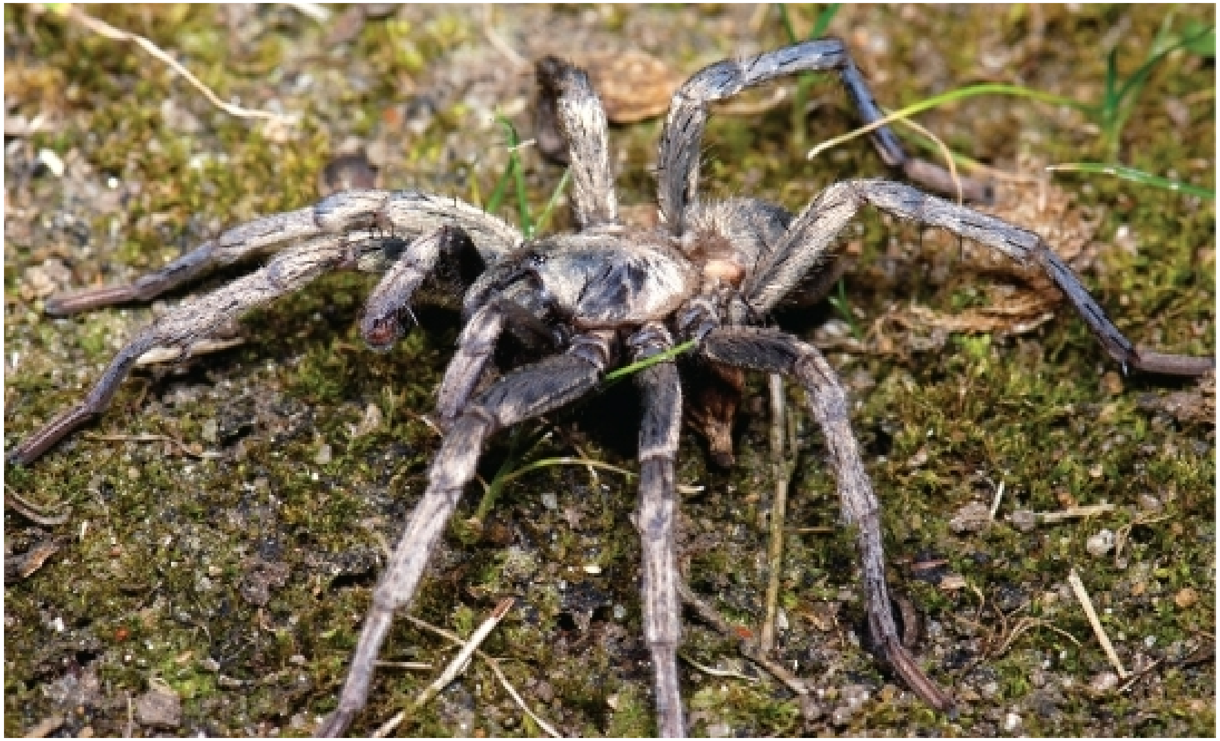
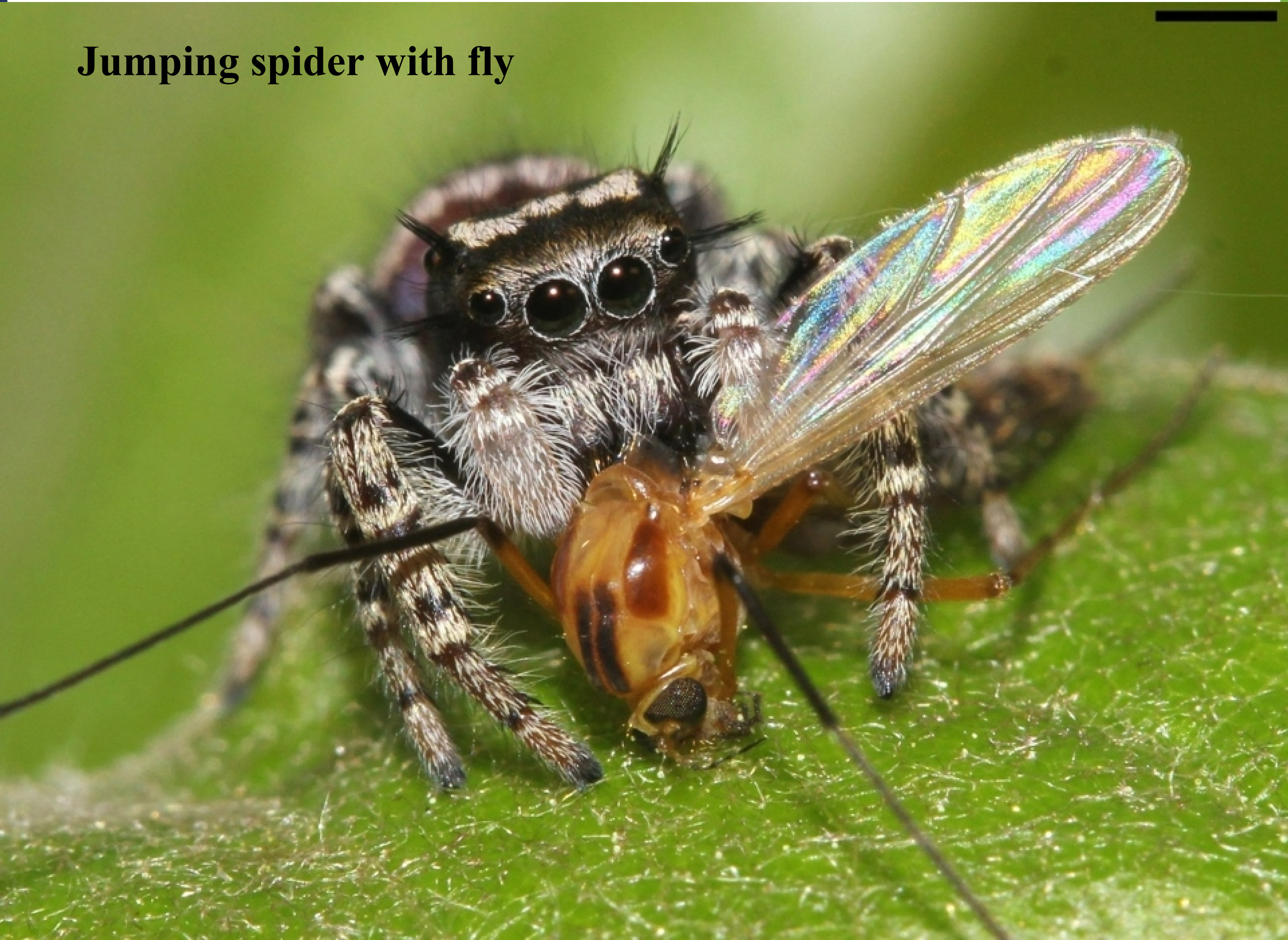


FIGURE 28.43

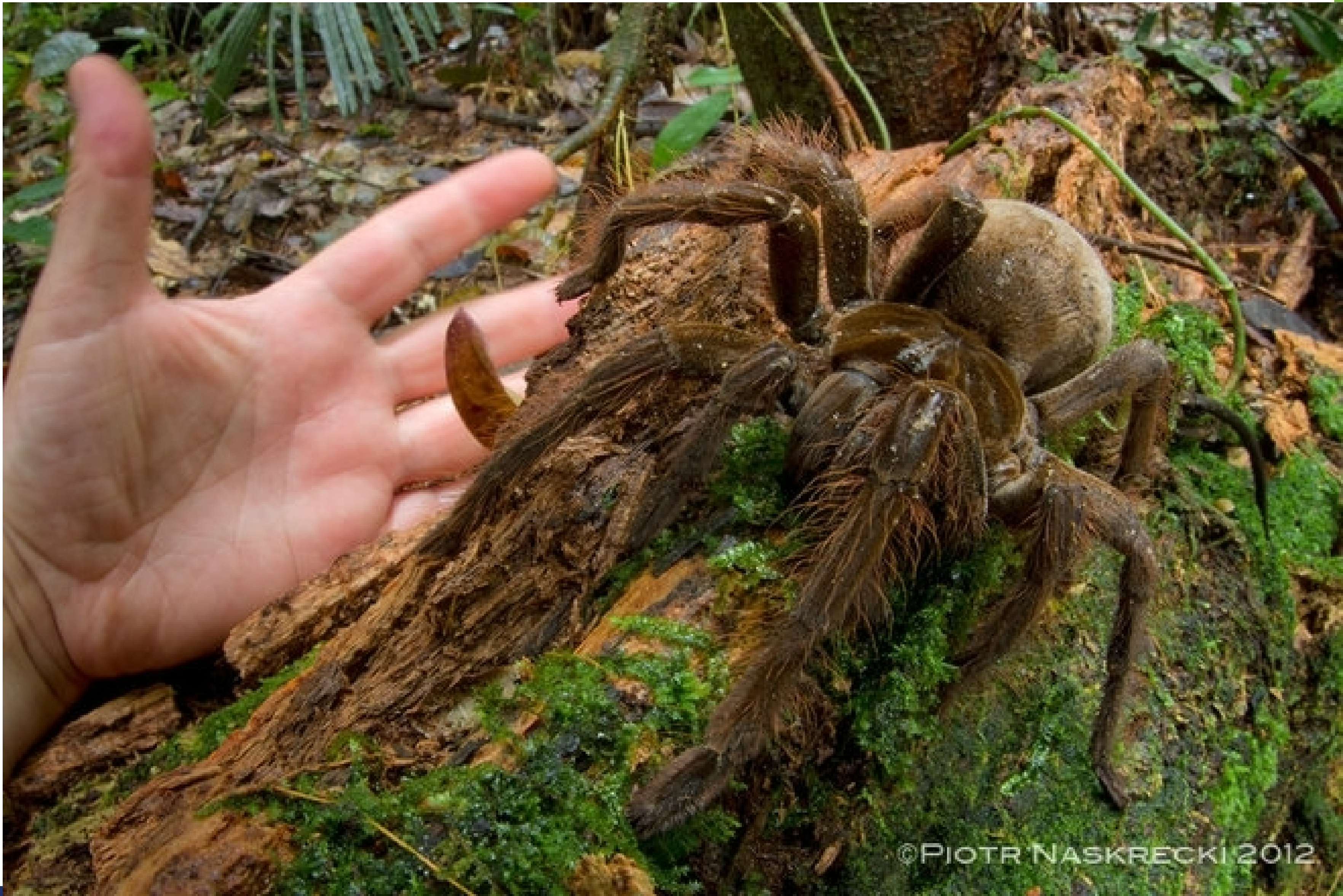


The trapdoor spider, like all spiders, is a member of the subphylum Chelicerata. (credit: Marshal Hedin)

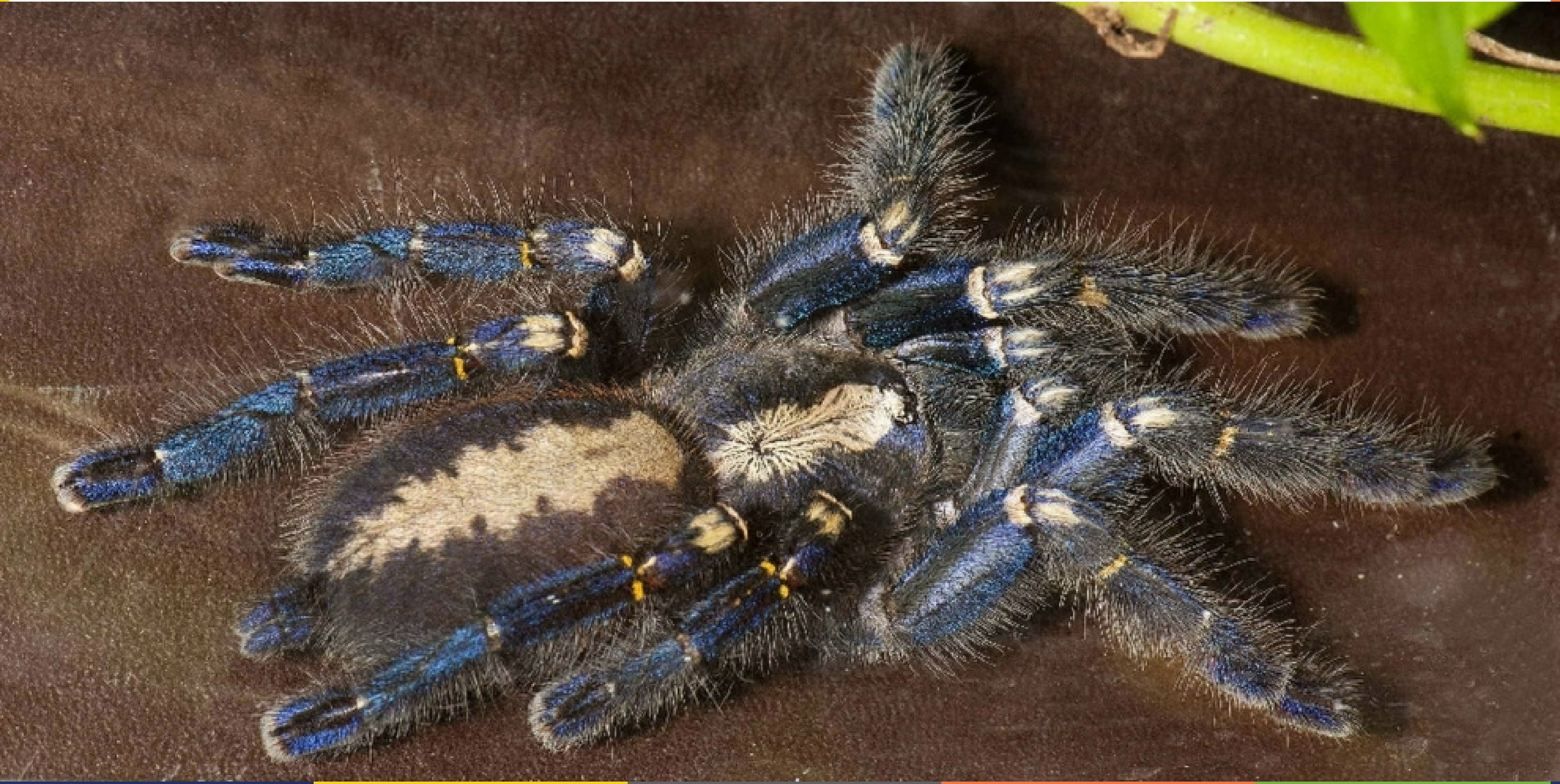
Jumping spider with fly



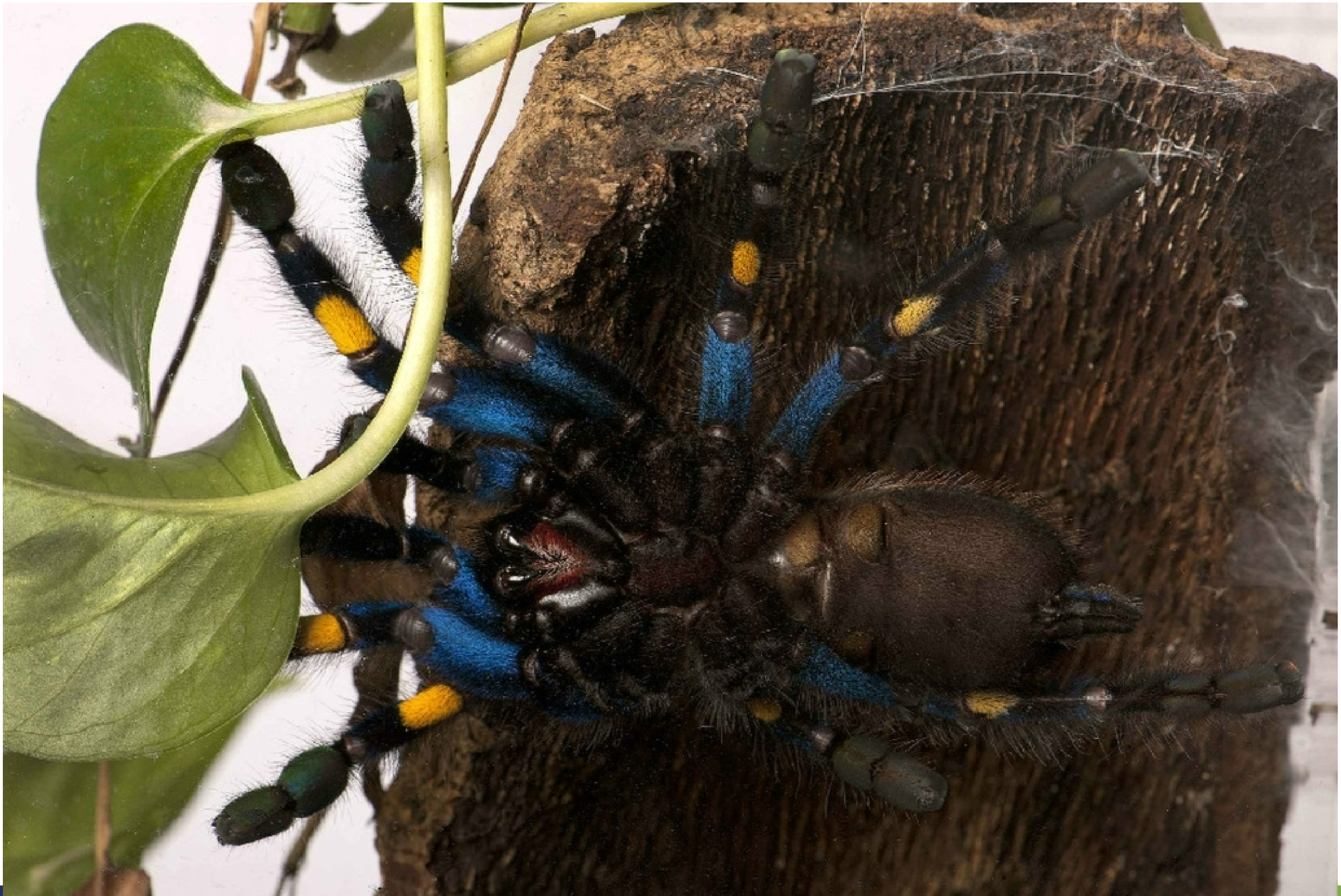
GOLIATH BIRDEATER SPIDER



GOOTY SAPPHIRE ORNAMENTAL SPIDER (DORSAL)



GOOTY SAPPHIRE ORNAMENTAL SPIDER (VENTRAL)



SPIDERS

Silk

- Protein with repeating sequence of amino acids glycine-alanine
- Stored as gel prior to spinning
- Chemical modification when forced through spinnerets

Functions of silk:

- Webs
- Line retreats
- Safety lines
- Wrapping eggs
- Dispersal of young (ballooning)

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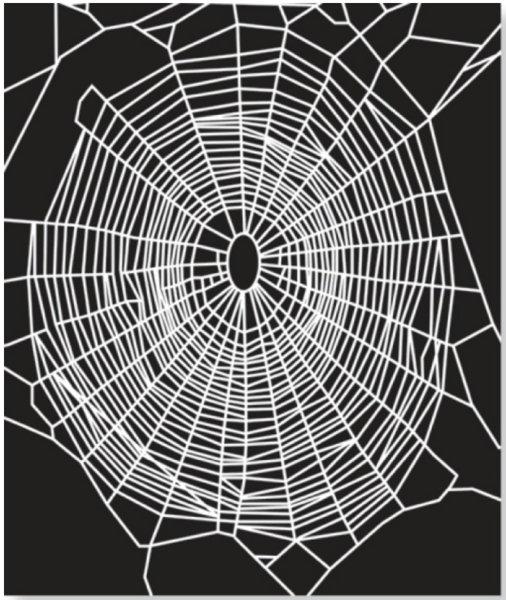

(a) Normal web

(b) Web spun by spider fed with prey containing caffeine

(c) Web spun by spider fed with prey containing marijuana

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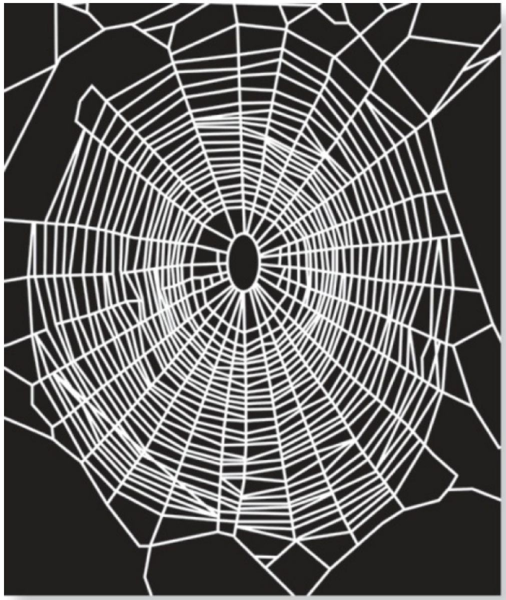
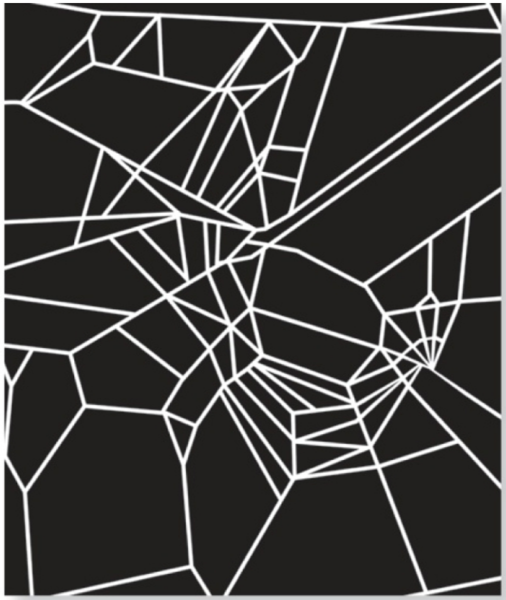


(a) Normal web



(b) Web spun by spider fed with prey containing caffeine

(c) Web spun by spider fed with prey containing marijuana

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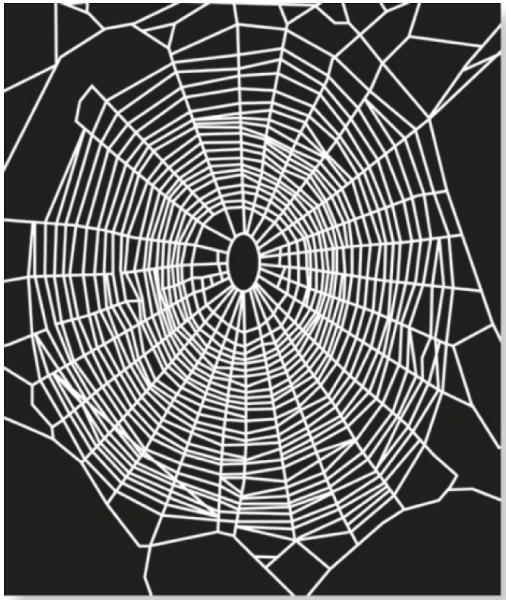
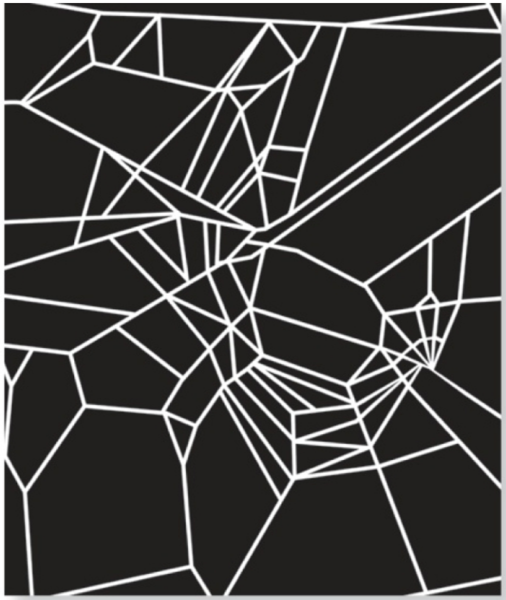
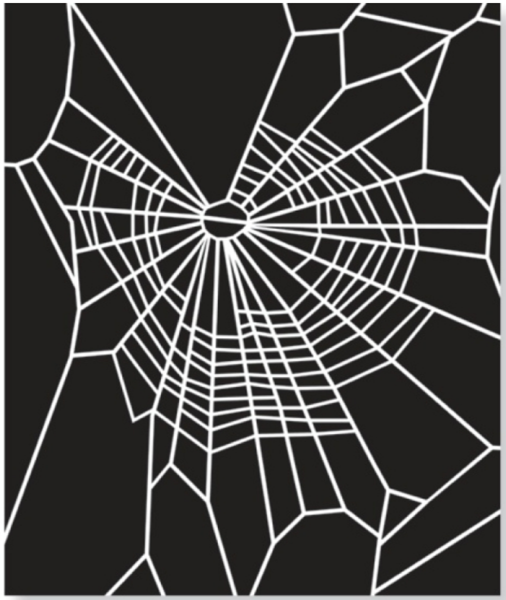


(a) Normal web



(b) Web spun by spider fed with prey containing caffeine



(c) Web spun by spider fed with prey containing marijuana

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SPIDERS

Excretion

- Malpighian tubules (like kidneys – excretory)
- Regulate potassium and water to be efficient in dry environments

Sensory

- 8 simple eyes
- Hairlike setae

SPIDERS

Reproduction

- Often have courtship rituals
- Males store sperm packets in pedipalps and transfer to female

Venom

- Most are not dangerous to humans
- Few can have severe or fatal bites

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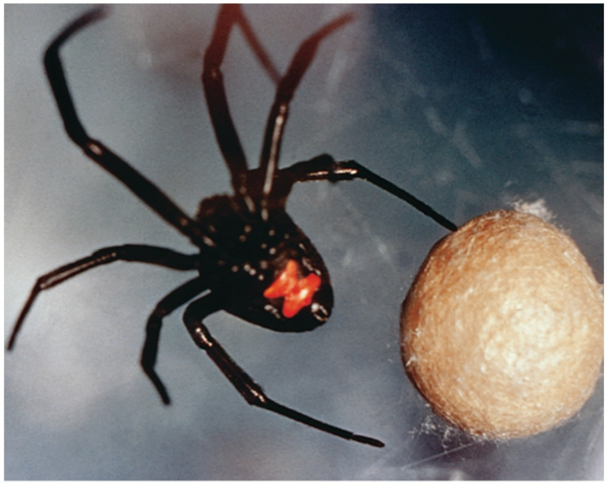
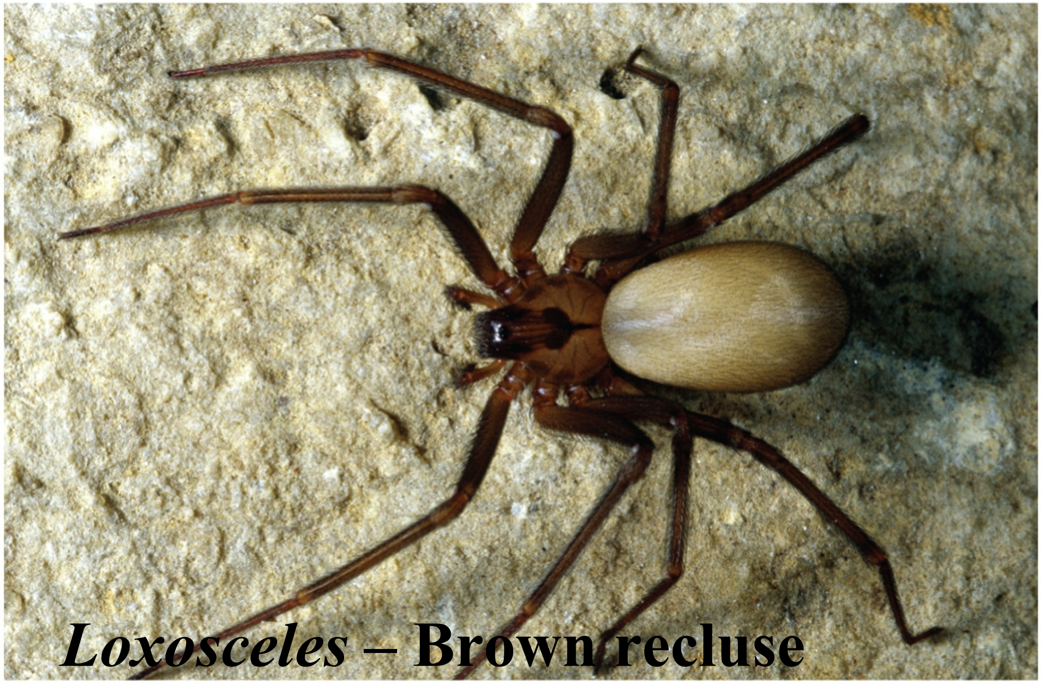


A

Latrodectus – **Black widow**



Loxosceles – **Brown recluse**

B

a: CDC; b: © Gregory G. Dimijian, M.D./Science Source

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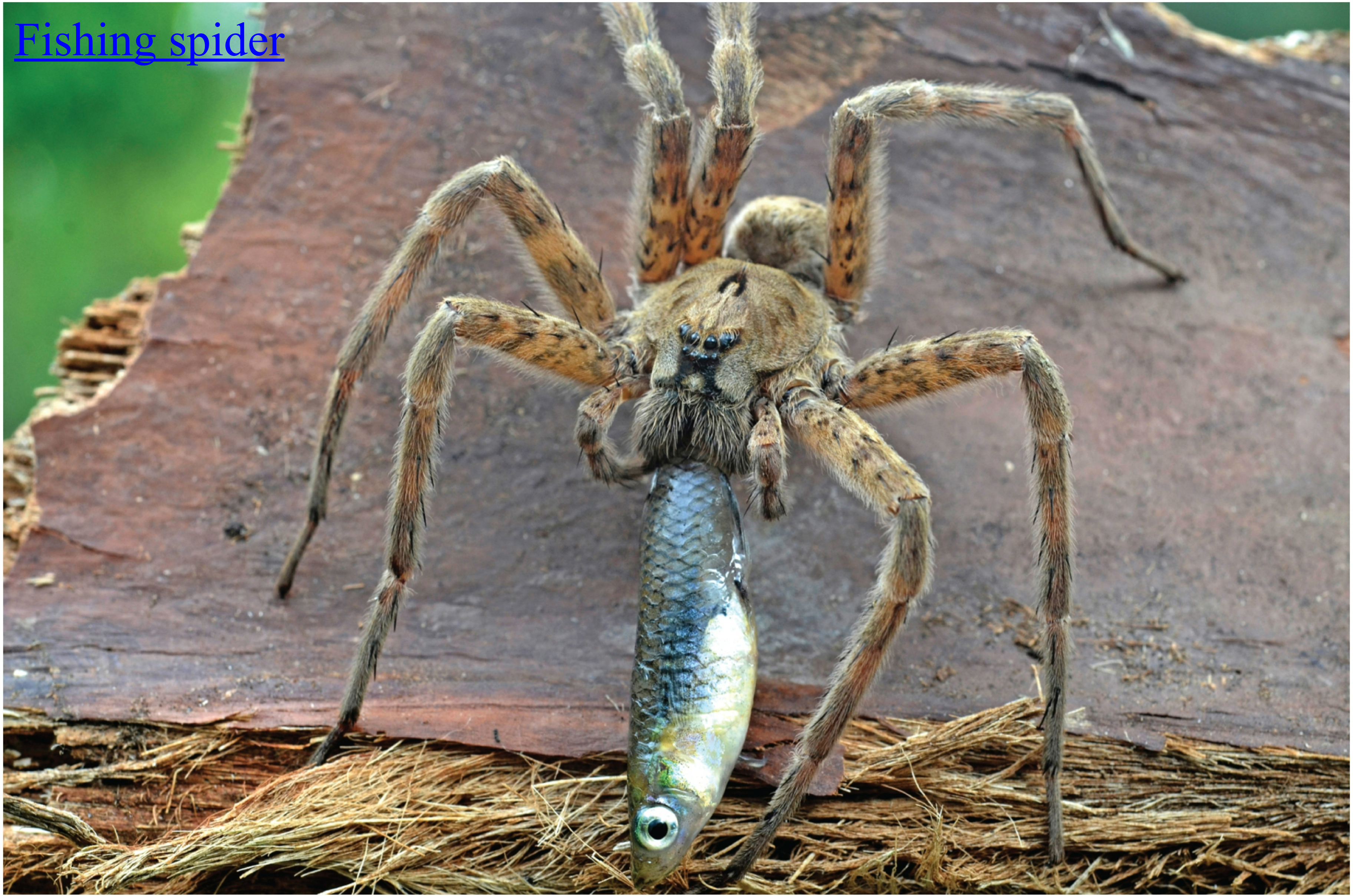
Fishing spider



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ORDER SCORPIONIDA

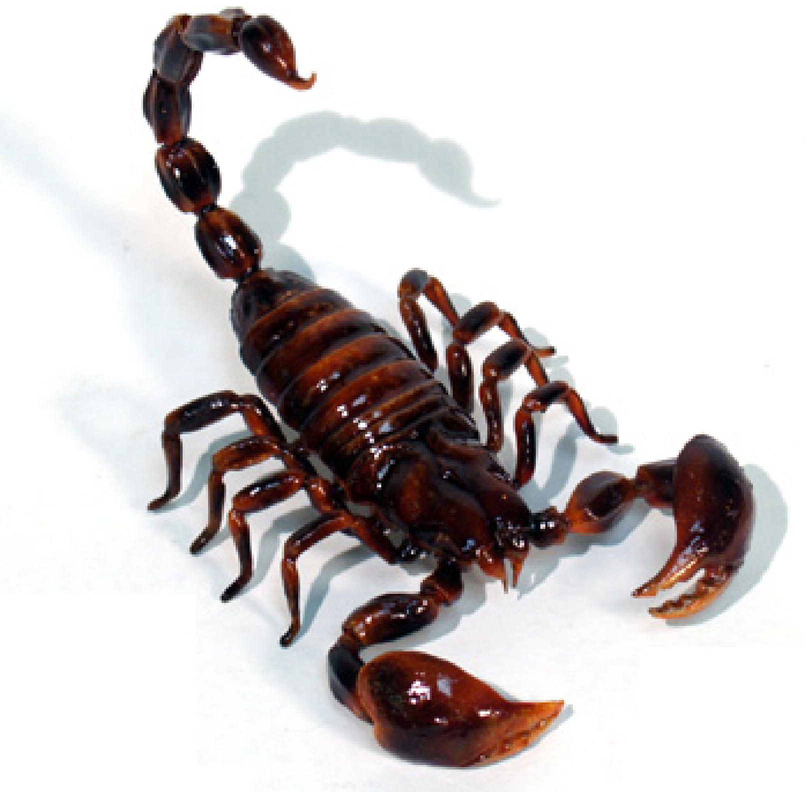
Scorpions

All predaceous

- Pedipalps to capture prey
- Chelicerae to rip apart

Short cephalothorax (has appendages), abdomen with stinging apparatus

Well developed young with maternal care



Hadurus spadix Stahnke, 1940
Copyright © 1997 R. David Gaban

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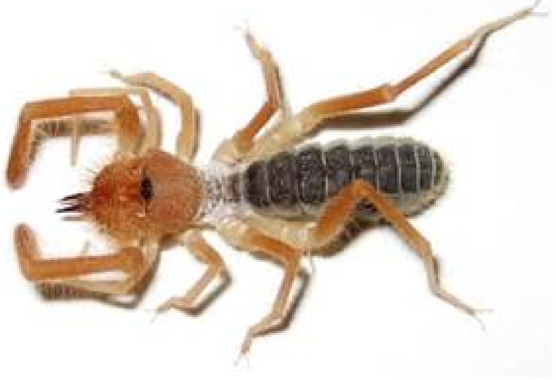
d. Order Solpugida

Solpugids (sun or camel spiders)

Large chelicerae to shred prey

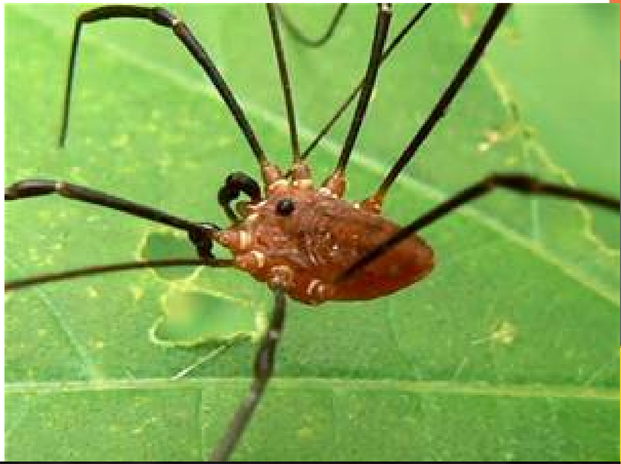


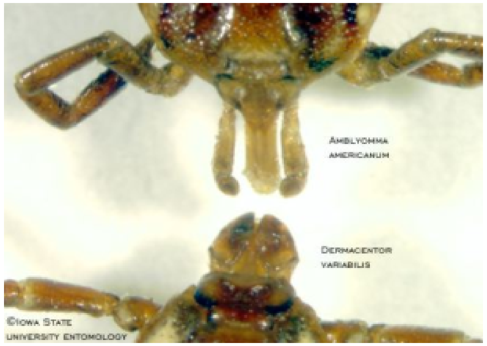
e. Order Opiliones

Harvestmen

No constricting between head-thorax and abdomen

Legs easily shed if grasped





ORDER ACARI

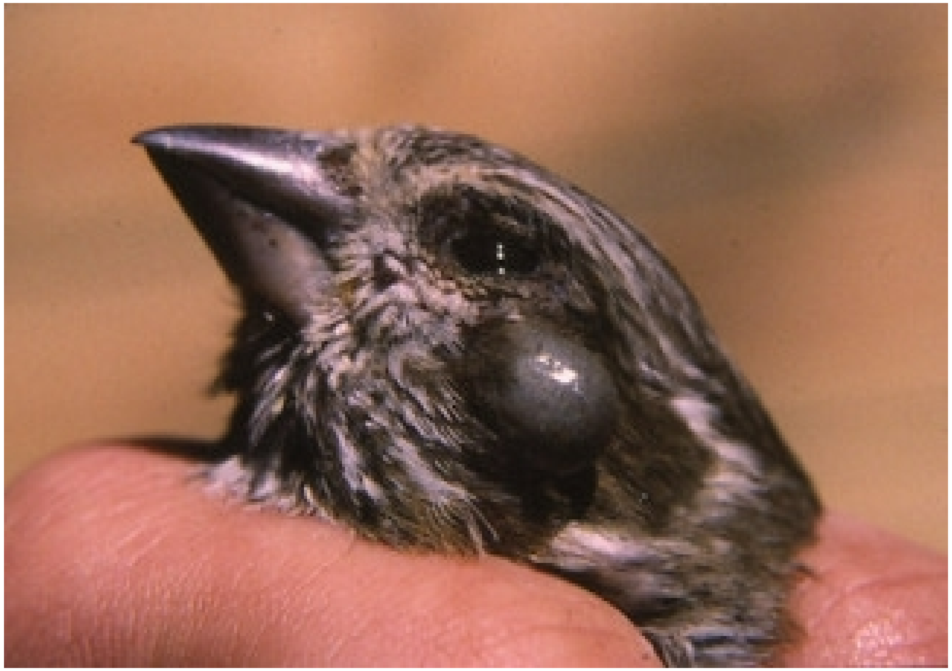
Ticks and mites

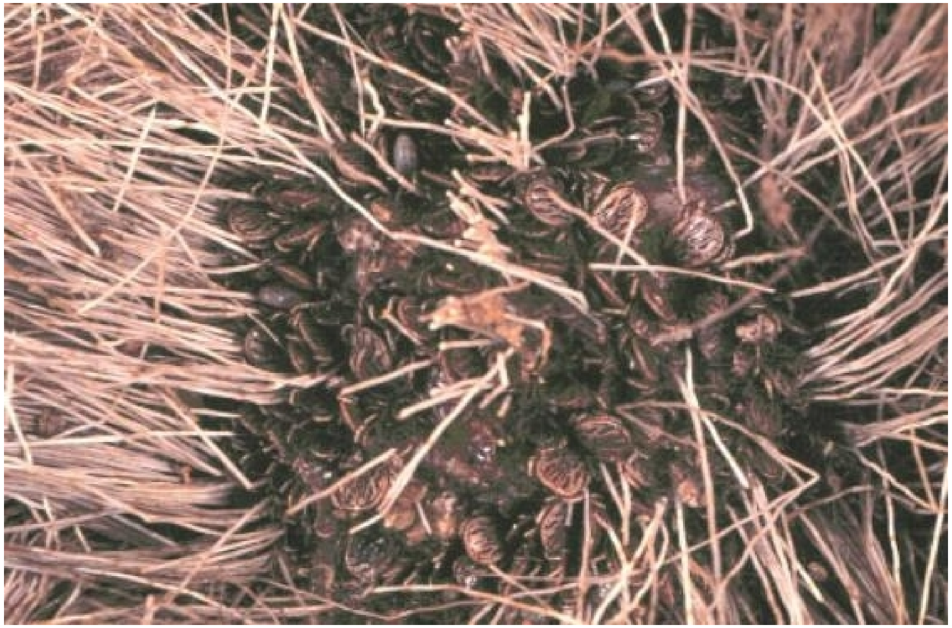
Cephalothorax and abdomen completely fused

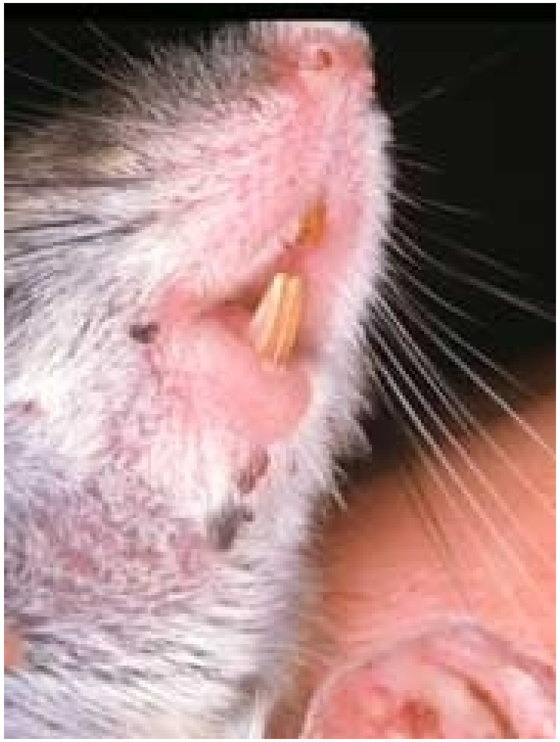
Mouth parts different on each species.

Some are free living while others are parasites

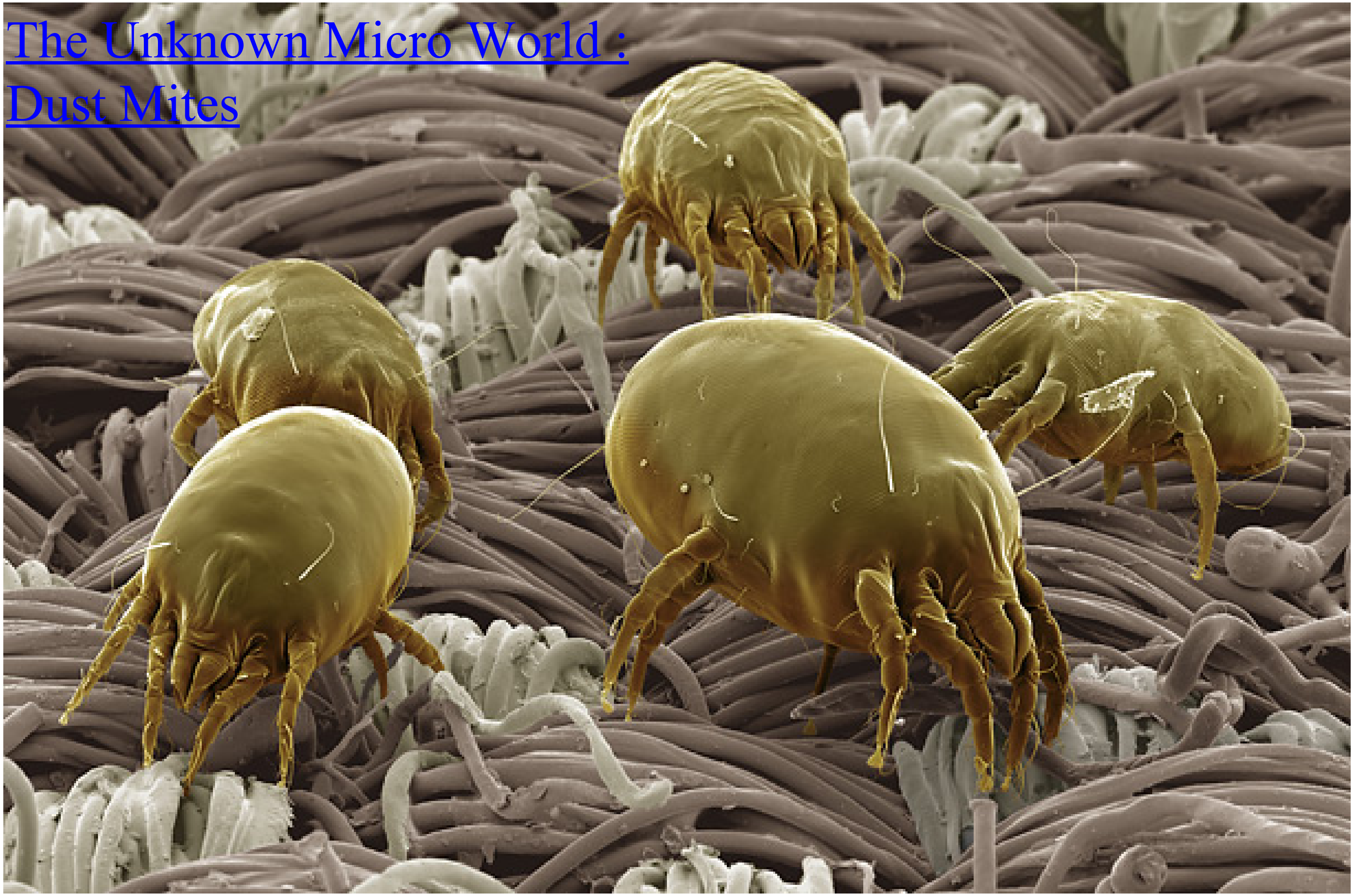
Can transmit diseases and can cause economic harm (Lyme’s disease, Rocky Mountain spotted fever, Encephalitis, Tularaemia)







Dermatophagoides



[The Unknown Micro World : Dust Mites]

House dust mite

2. SUBPHYLUM MYRIAPODA

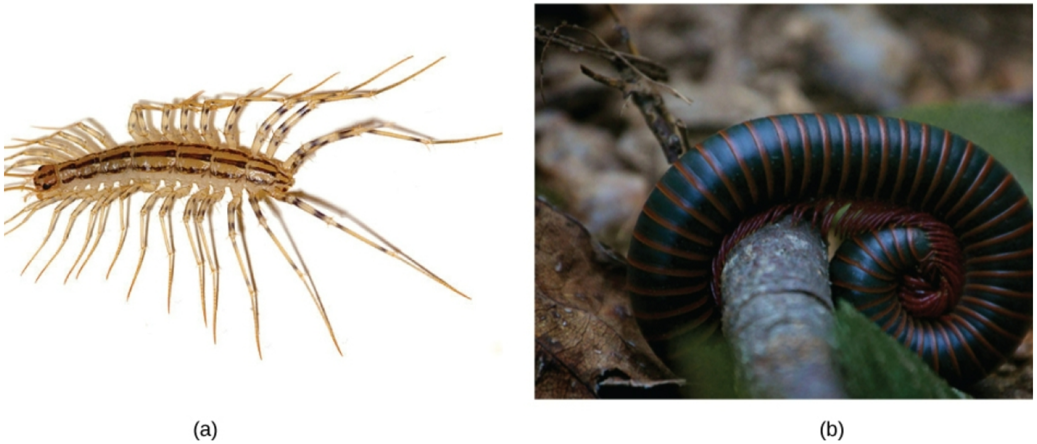
2 body sections

Head and trunk

1 pair of antennae

Mandible and 2 pairs of maxillae

1 or 2 legs on each side of each segment


(a) (b)

(a) The centipede *Scutigera coleoptrata* has up to 15 pairs of legs.

(b) This North American millipede (*Narceus americanus)* bears many legs, although not one thousand, as its name might suggest. (credit a: modification of work by Bruce Marlin; credit b: modification of work by Cory Zanker)

CLASS CHILOPODA = CENTIPEDES

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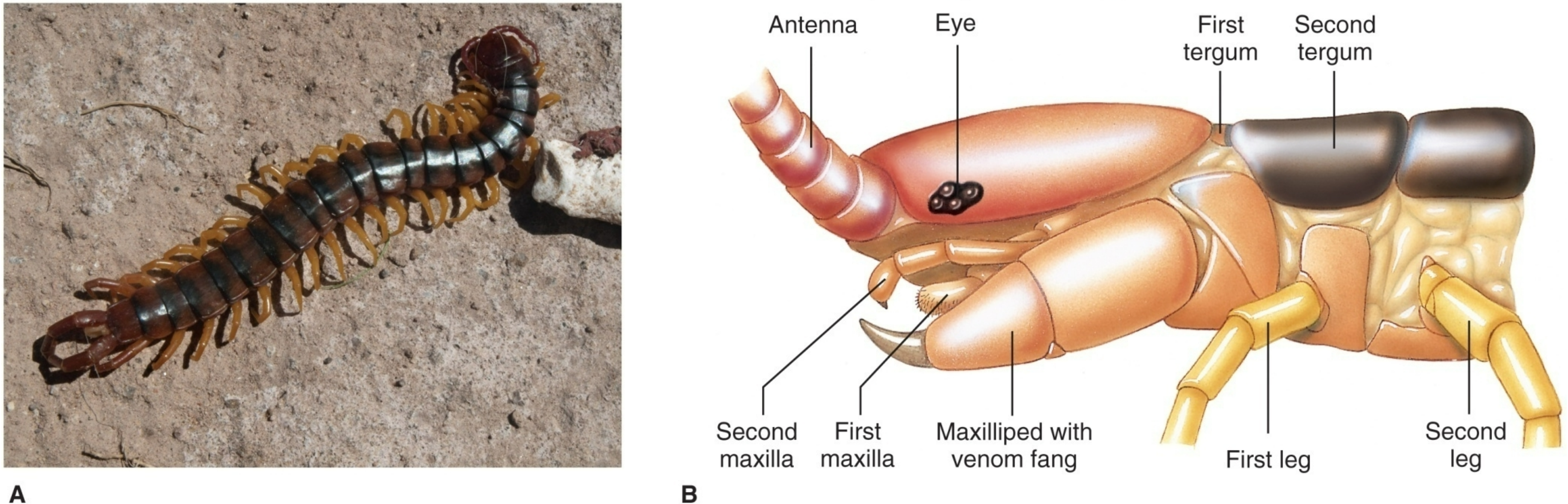
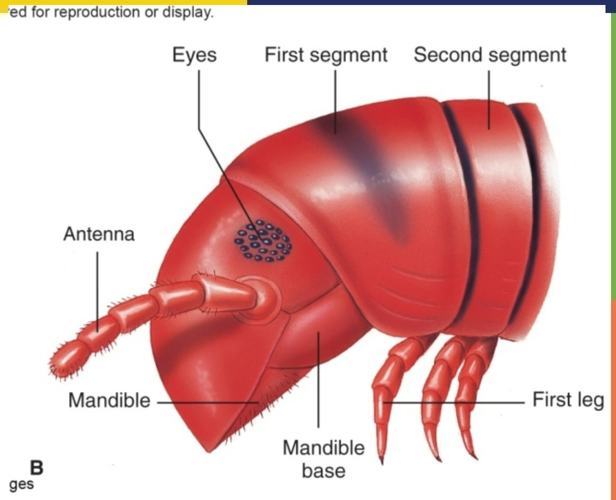


a: © Dave Moyer

- Predators
- Each segment contains one pair of legs (15-173 segments)
- Appendages on first segment are modified to venom claws
- Pair of eyes consists of group of ocelli

CLASS DIPLOPODA

Millipedes



Cylindrical bodies (round cross section)

2 pairs of legs per segment (2 segments fuse during development), except near the head. Born with 6 segments and only 3 pairs of legs, they gain more of each with each molt. (<20 to >300 segments, depending on species)

Typically herbivorous (eat decaying plant matter)

Glands produce hydrogen cyanide to repel animals.

CLASS DIPOLOPODA (MILLIPEDES)

3. SUBPHYLUM CRUSTACEA - ~ 30,000 SPECIES

CHARACTERISTICS

- **BIRAMOUS appendages**
- **2 pairs of ANTENNAE**
- **1 pair of MANDIBLES and 2 pairs of MAXILLAE**
- **HEAD, thorax (the two often fused), and abdomen**
- **Compound and simple eyes**

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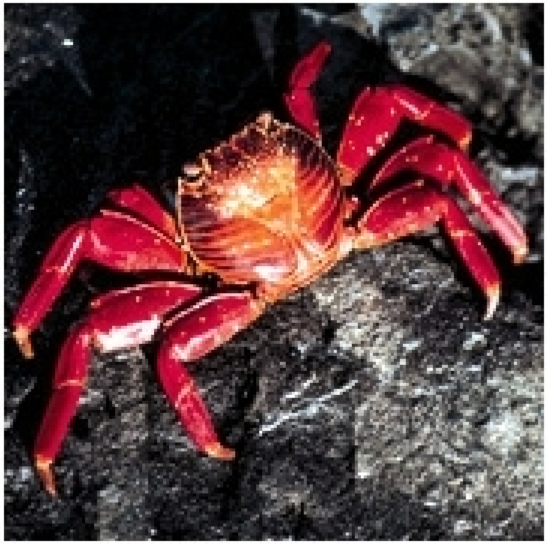
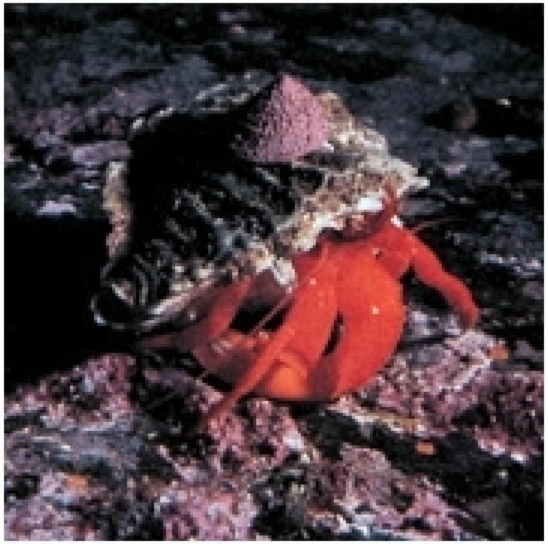
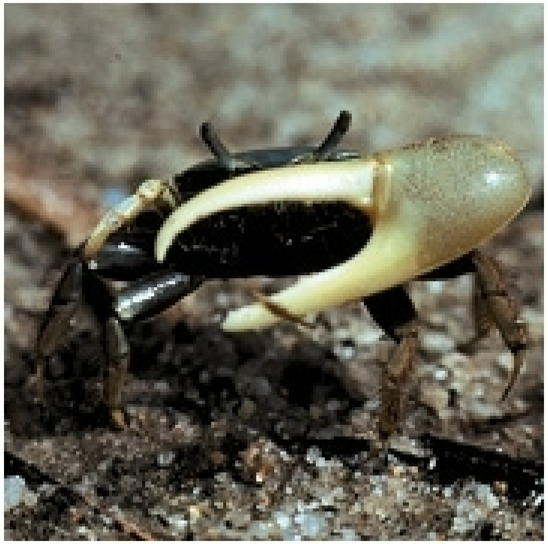
Living decapod crustaceans



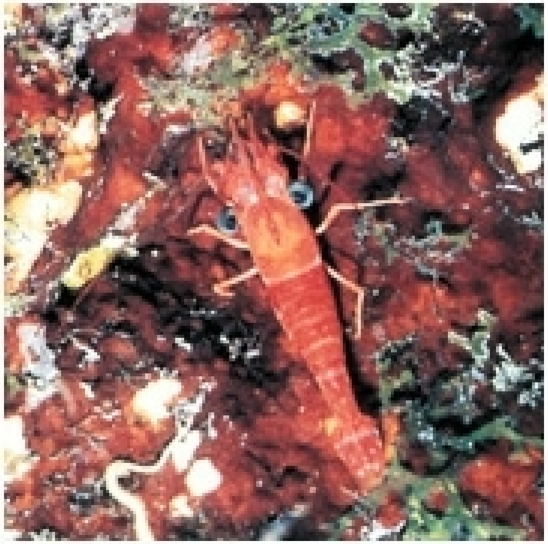
A Cleveland P. Hickman, Jr.



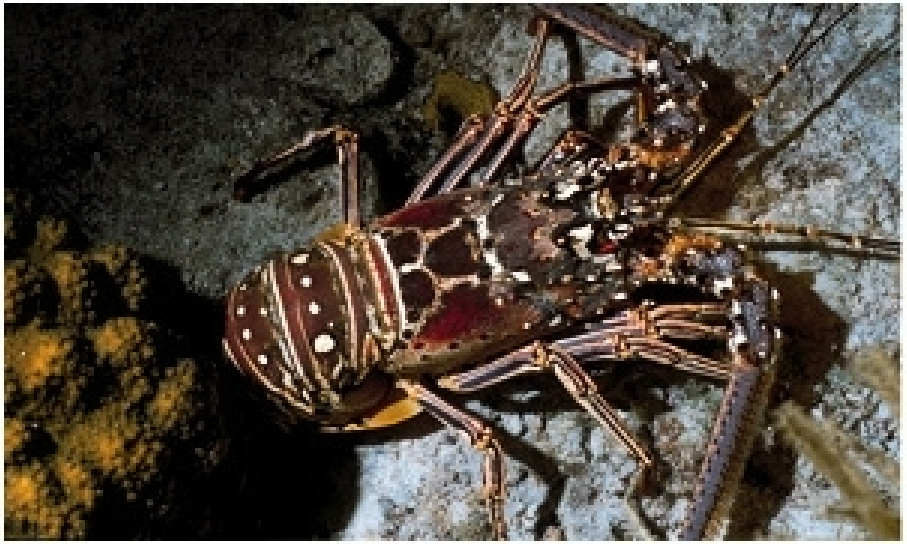
B Cleveland P. Hickman, Jr.



C Cleveland P. Hickman, Jr.



D Larry S. Roberts



E Larry S. Roberts

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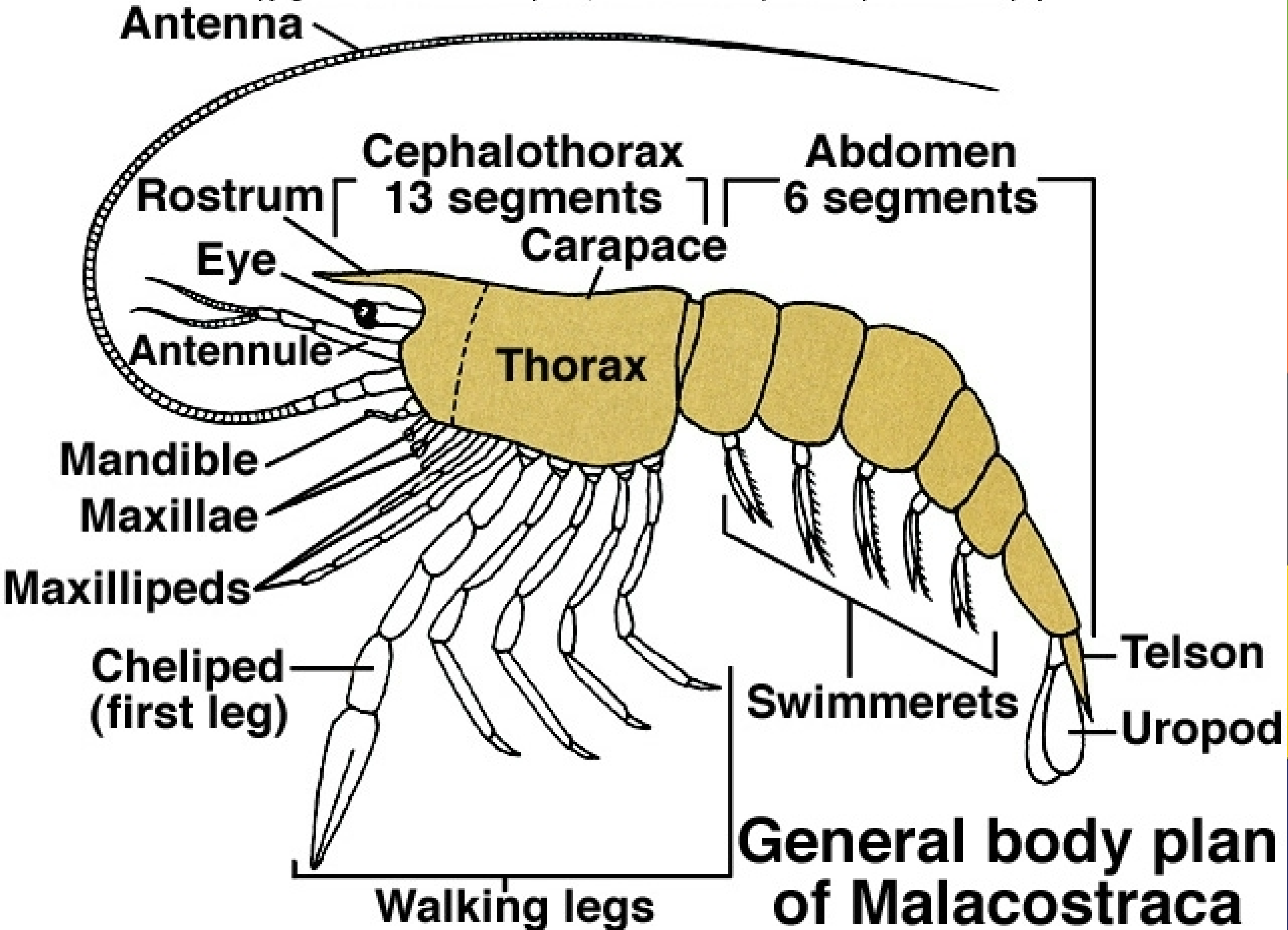
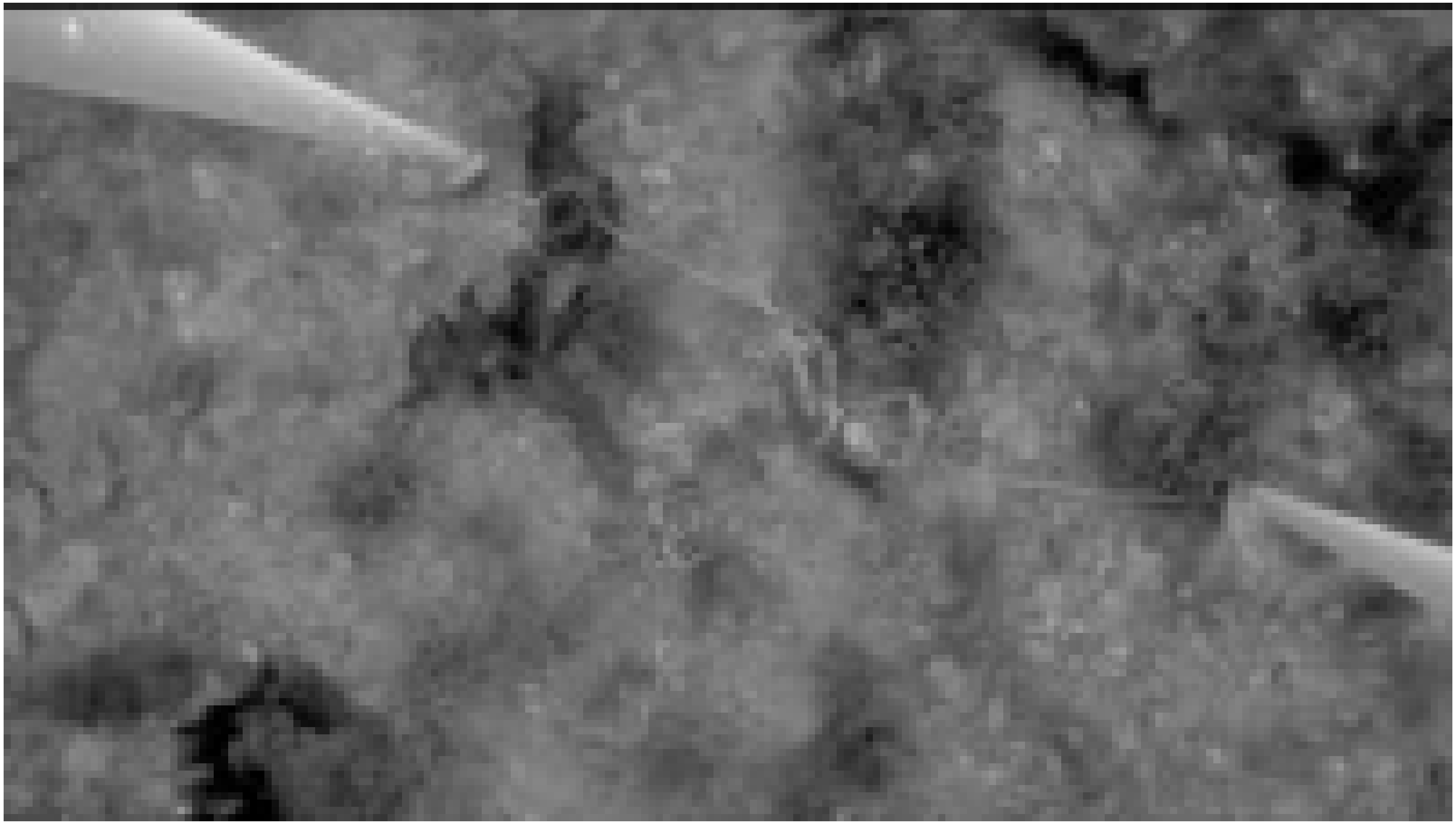


General body plan of Malacostraca

LOBSTER CHELIPEDS



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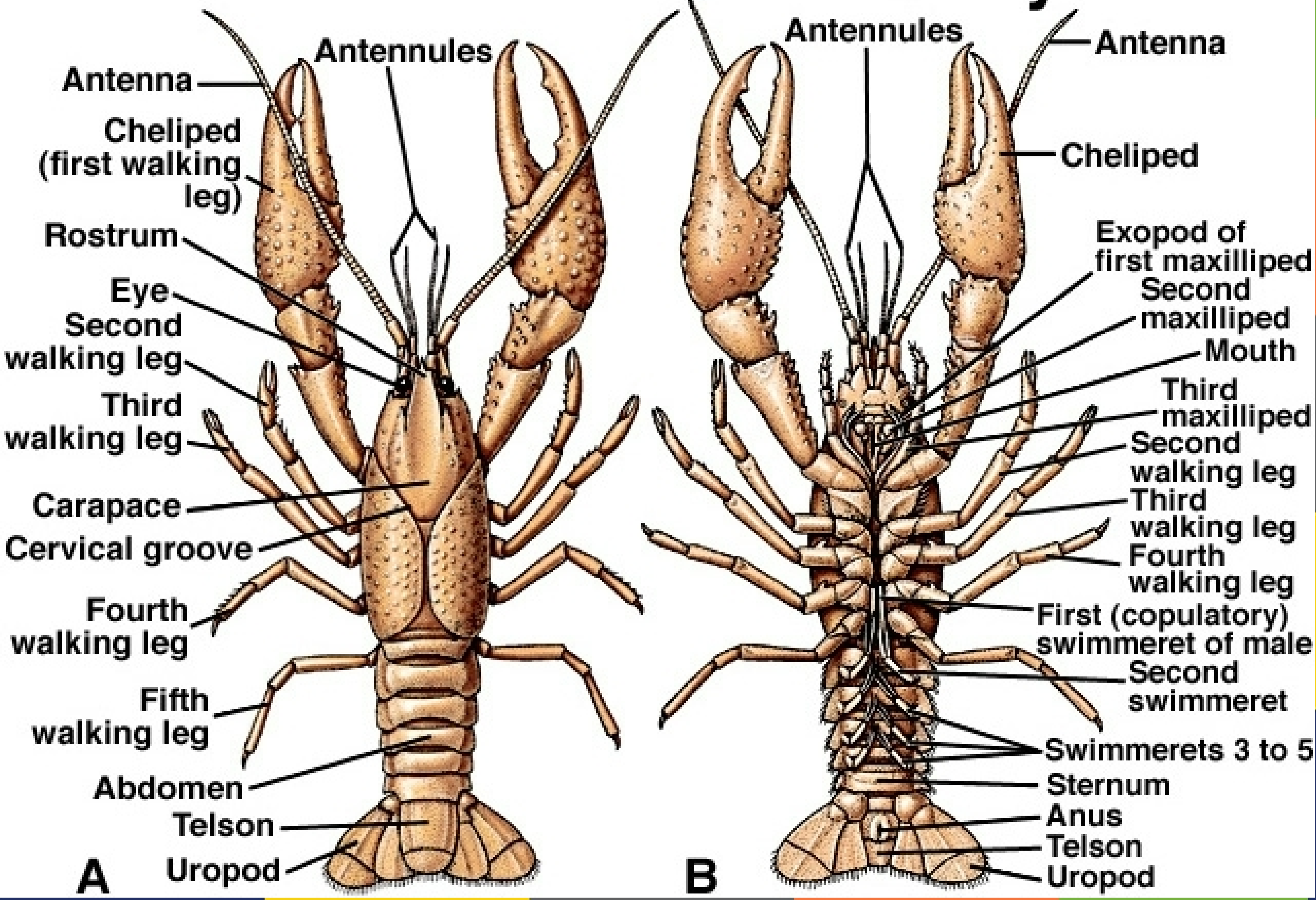
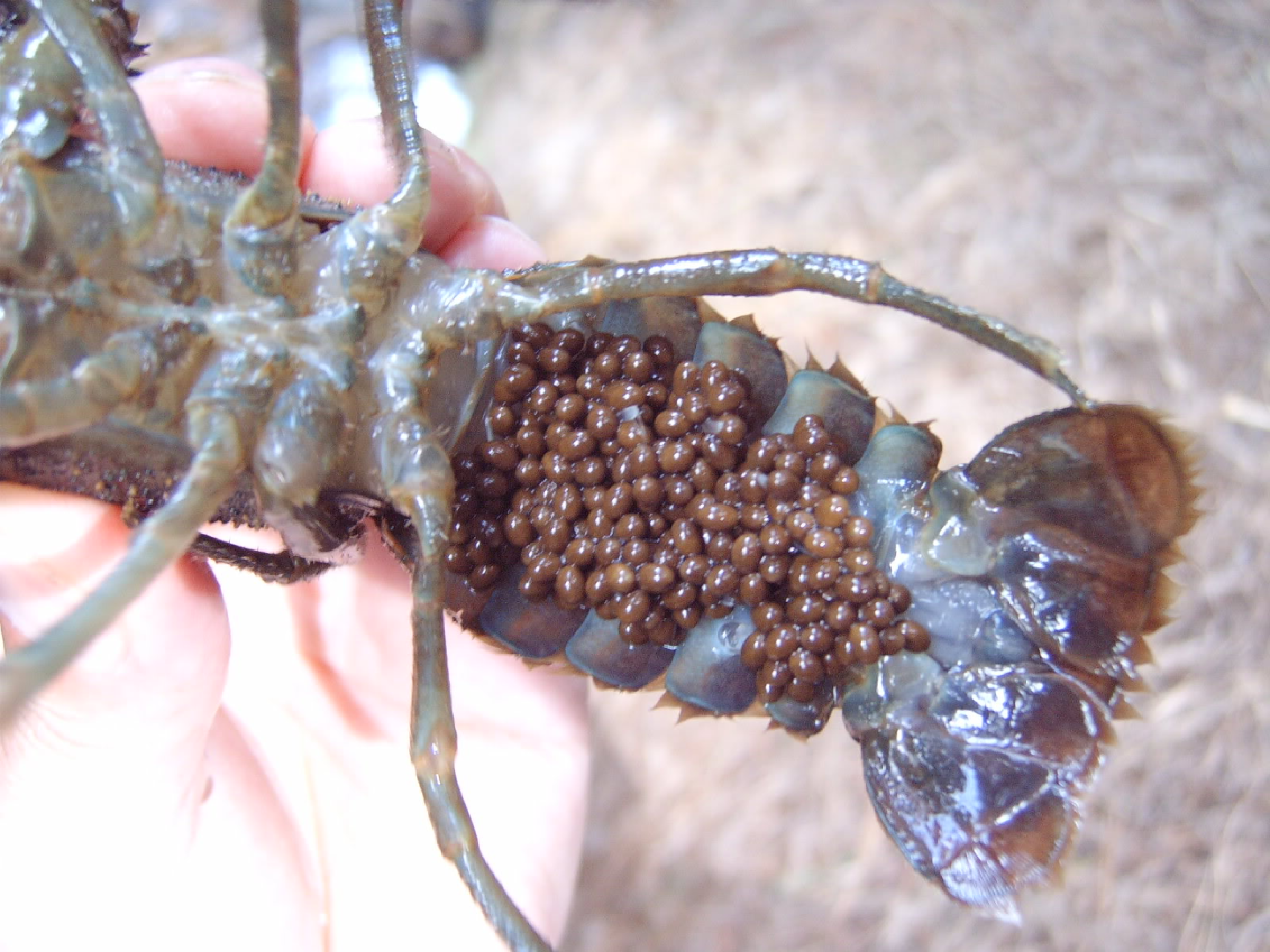
External structures of crayfish





PHYLUM ARTHROPODA

Ecdysis

- Molting occurs often in young animals and may cease in adults
- Necessary for a crustacean to increase in size the
    - Exoskeleton does not grow
- Underlying *epidermis* secretes cuticle
- contains protein, calcium salts, and chitin
- Hermit crab with glass shell

Giant spider crab molt

GIANT SPIDER CRAB MOLT

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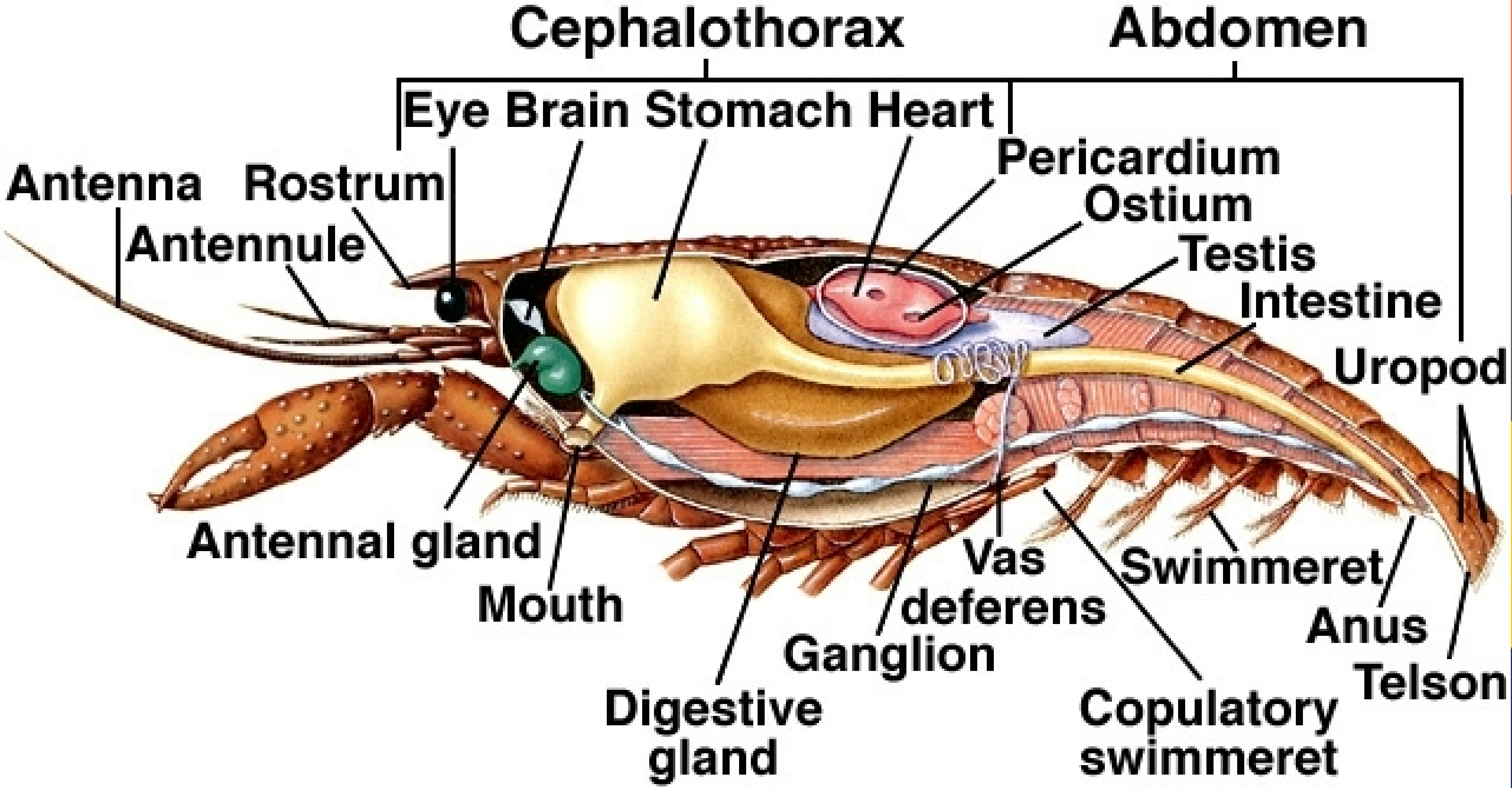
Internal structures of crayfish



SUBPHYLUM CRUSTACEA

- *Open circulatory system*
    - Depends less on heartbeats and more on movement of organs and limbs to circulate blood
- *Hemocyanin* (copper based) *and/or hemoglobin* (iron based) are respiratory pigments

SUBPHYLUM CRUSTACEA

Reproduction and Life Cycles

- Diversity of Reproduction
- Most crustaceans have separate sexes
  - *Most crustaceans* brood eggs in brood chambers, in egg sacs attached to the abdomen, or attached to abdominal appendages

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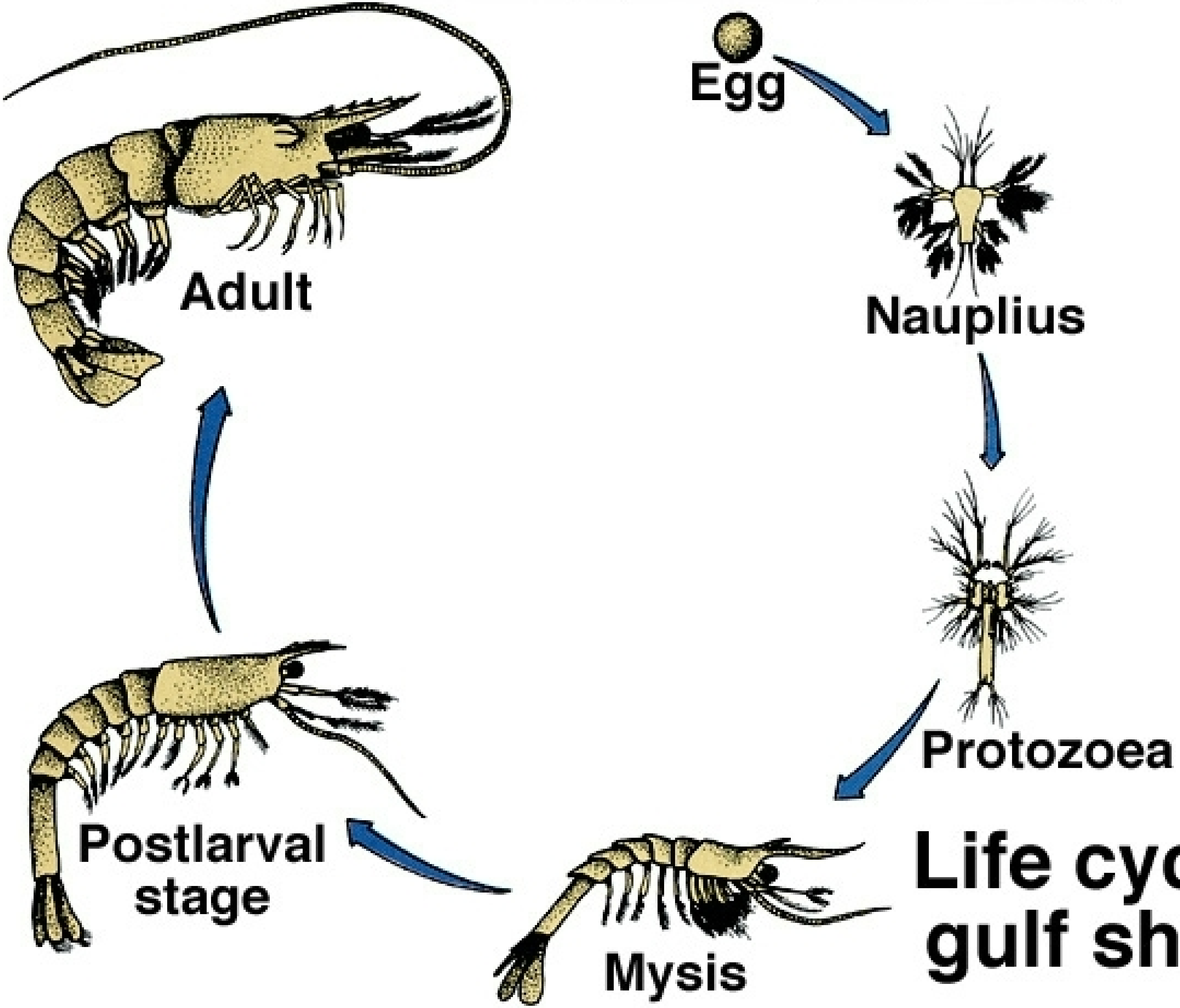

Life cycle of gulf shrimp

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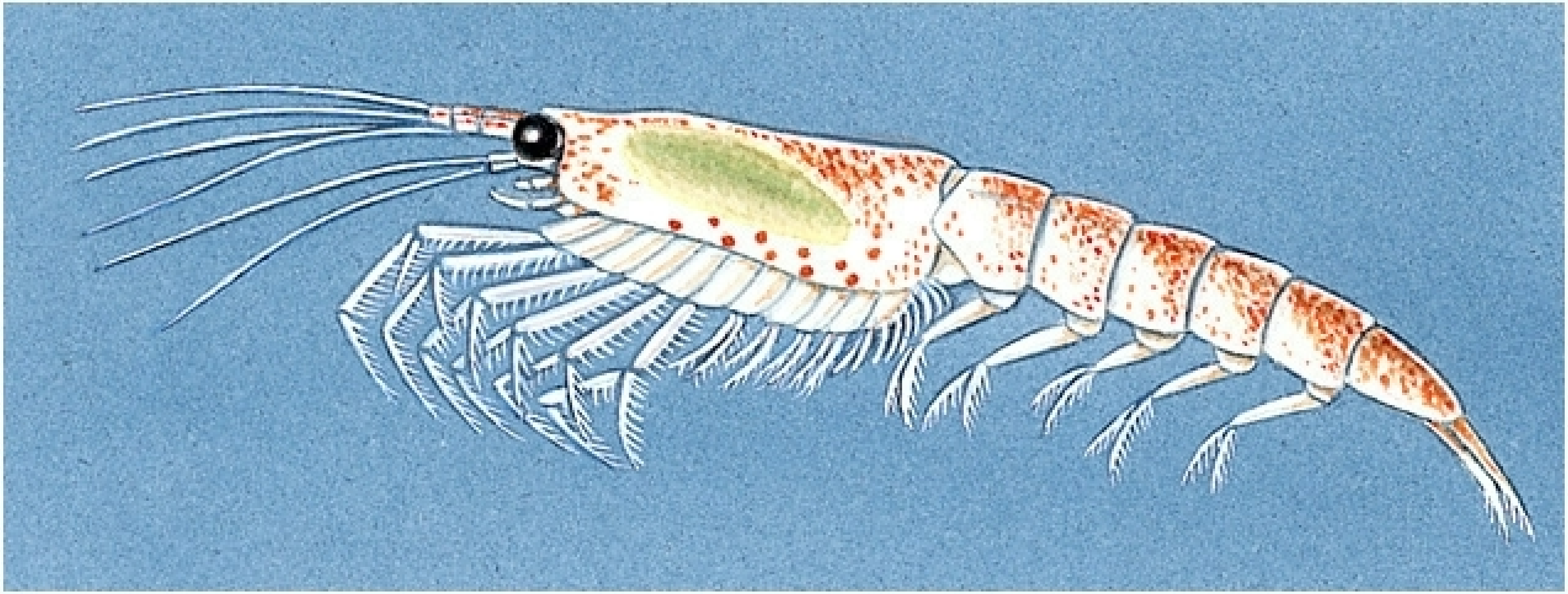
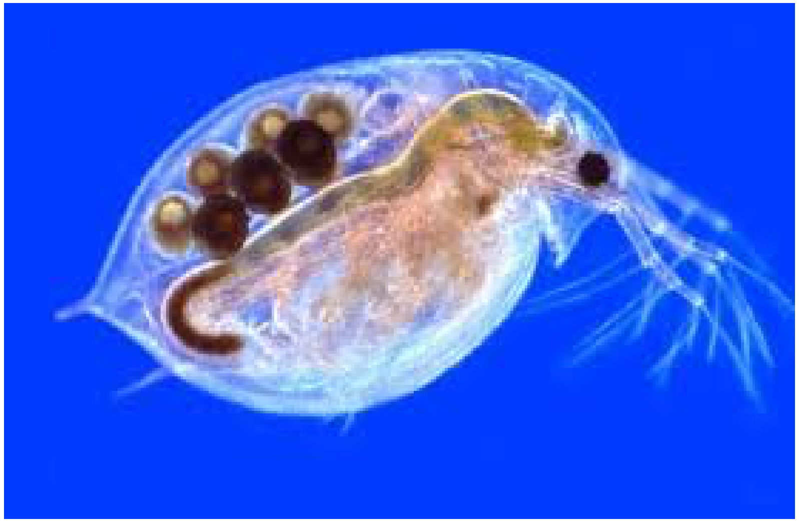
Meganyctiphanes "northern krill "



Class Branchiopoda

Flattened, *leaf-like legs (phyllopodia)* serve as respiratory organs, assist in suspension feeding, and in some, locomotion

Most are freshwater, important component of *freshwater zooplankton*



Daphnia

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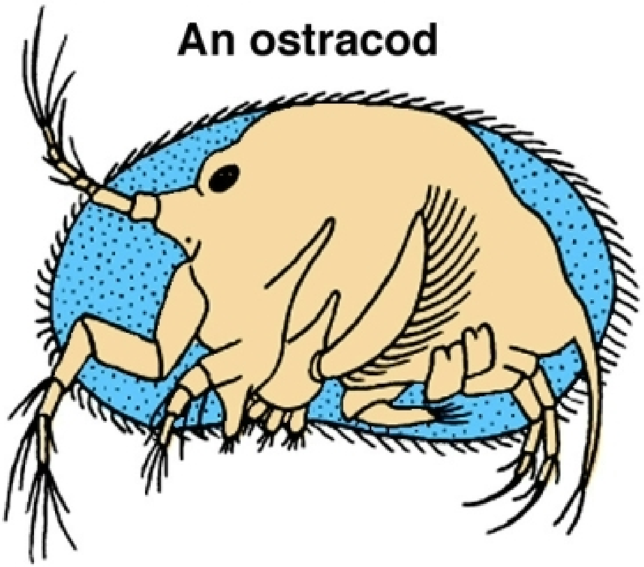
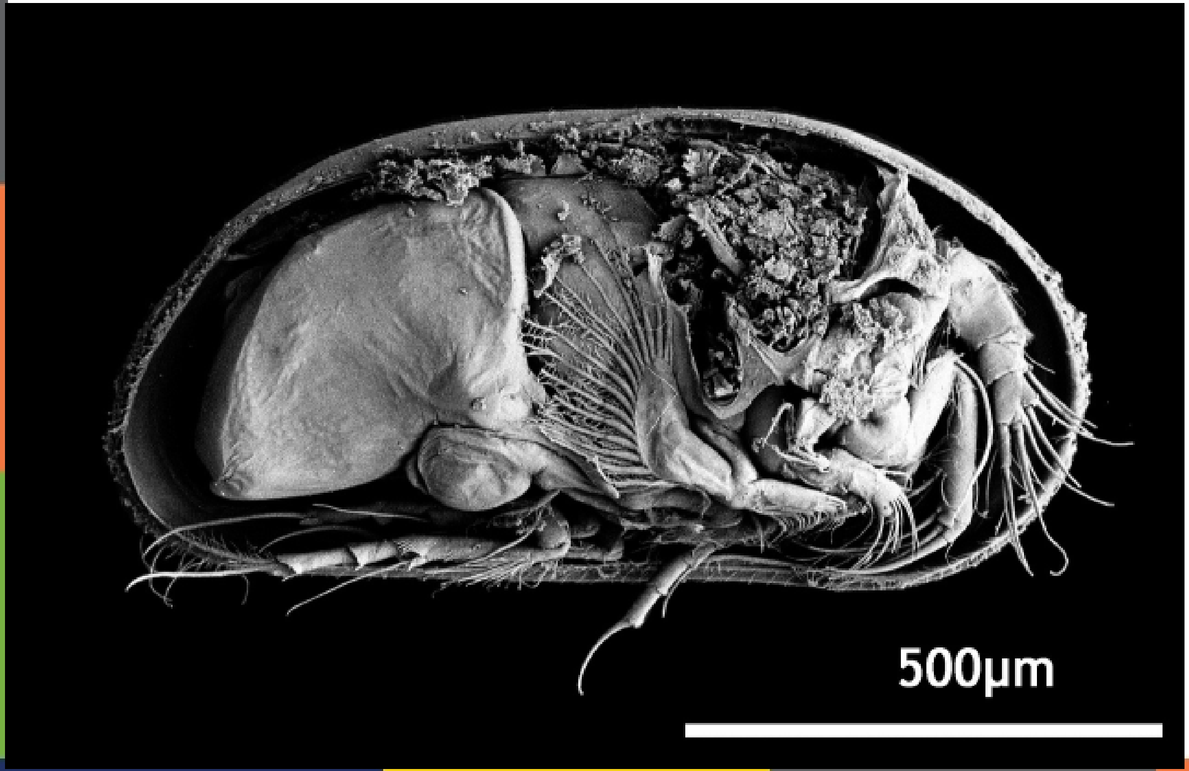


Class Ostracoda



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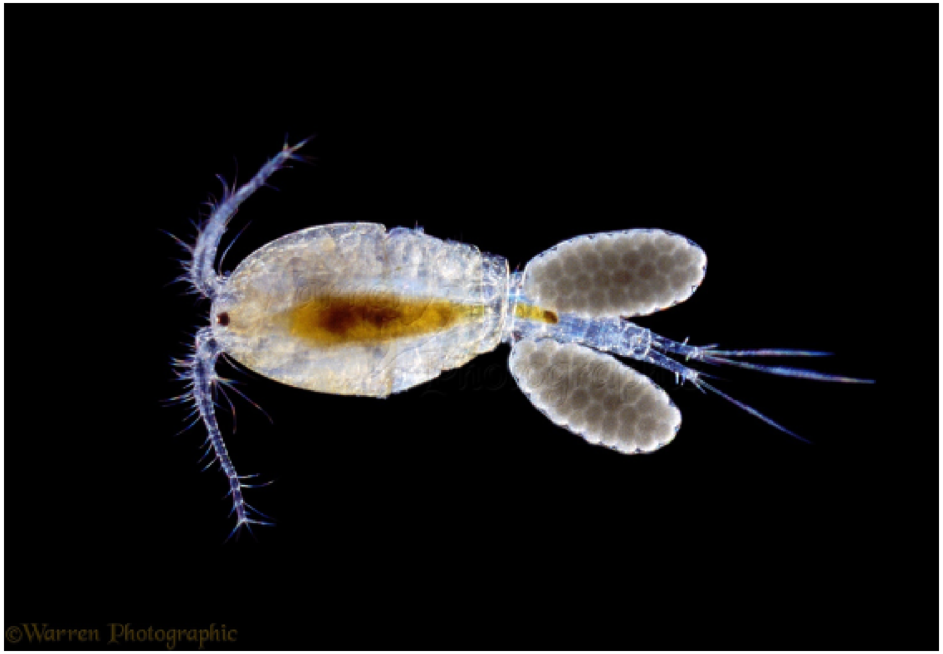
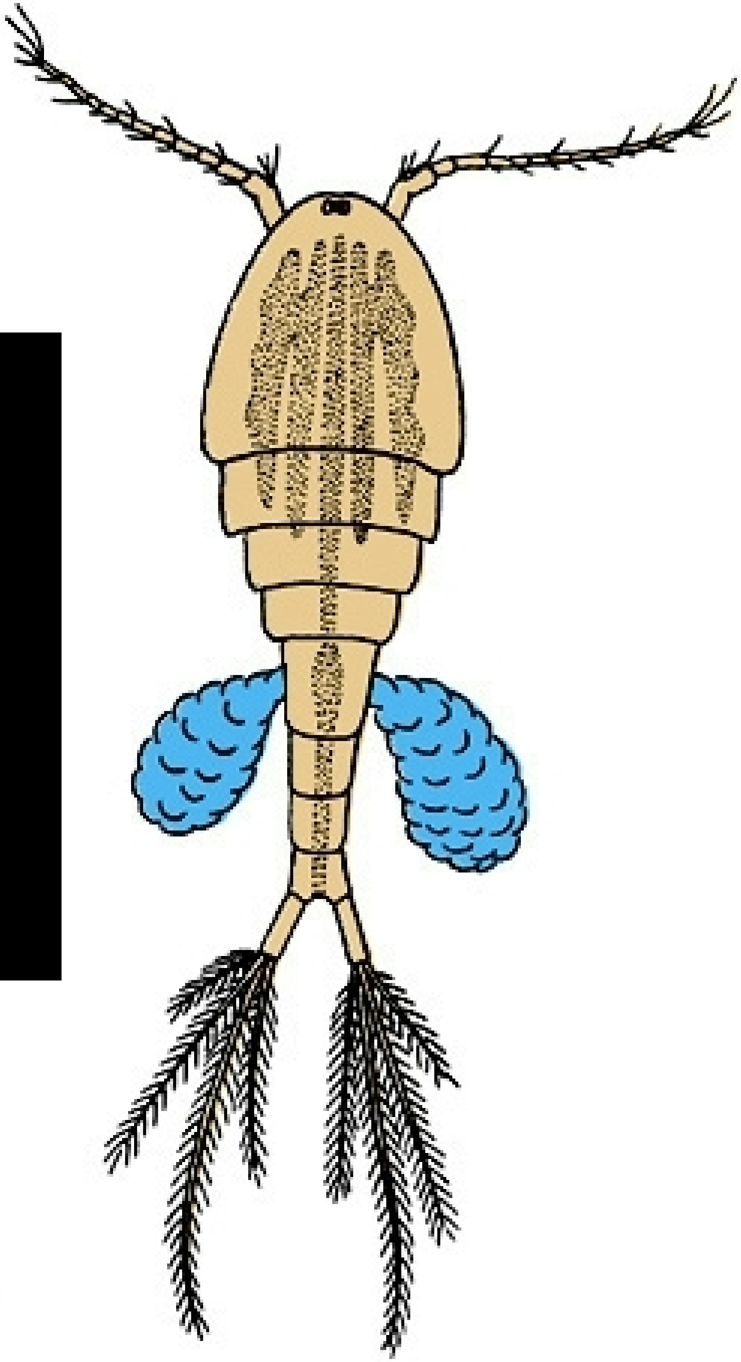
Class Copepoda

A copepod


©Warren Photographic



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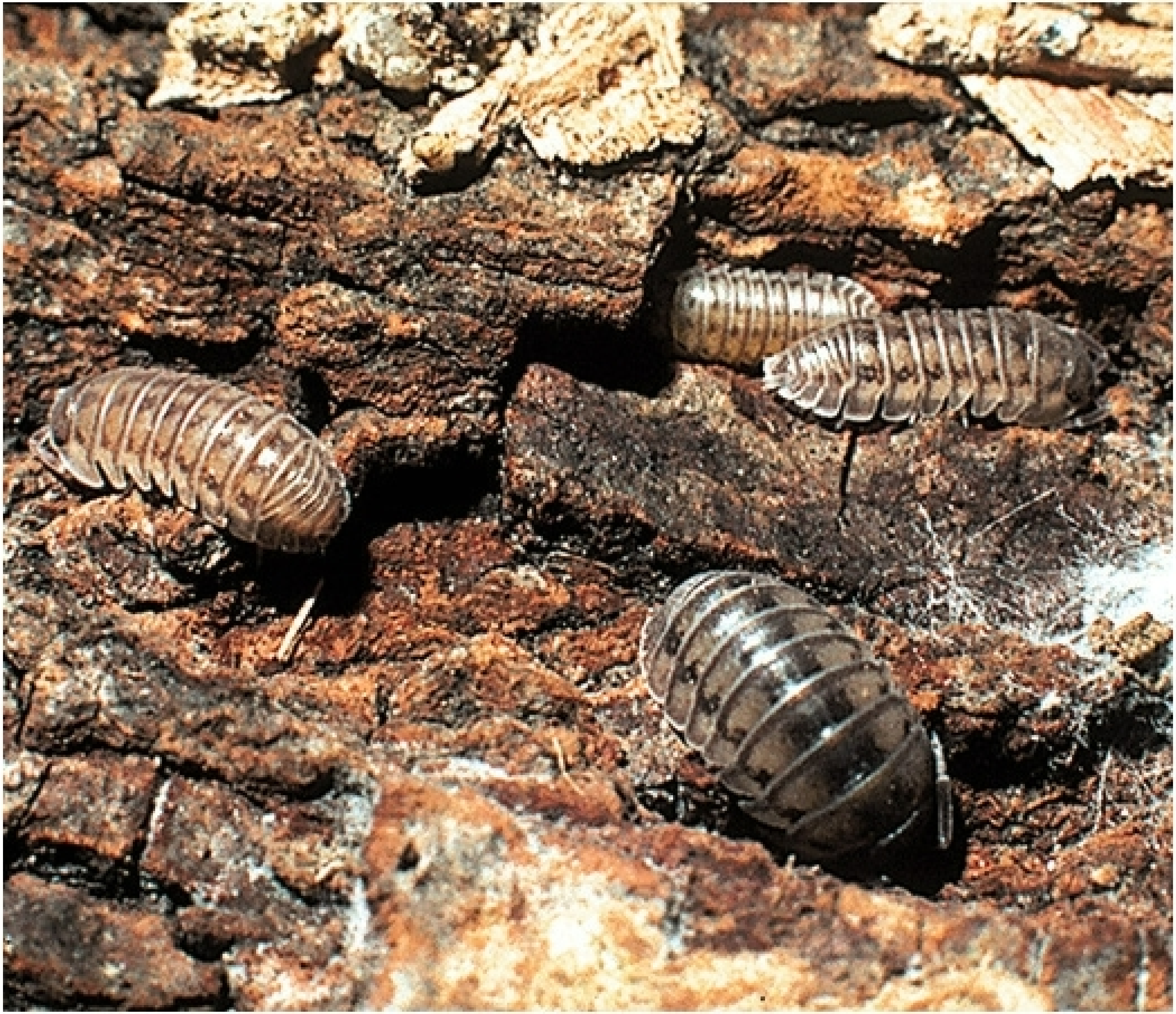
Pill bugs

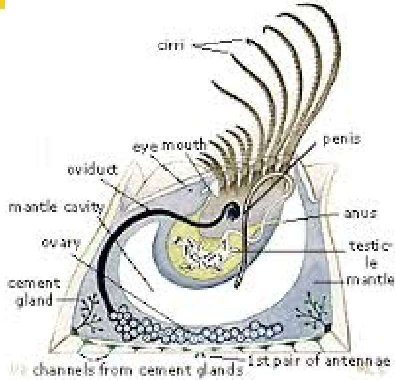
Class Isopoda



Cleveland P. Hickman, Jr.

SUBPHYLUM CRUSTACEA

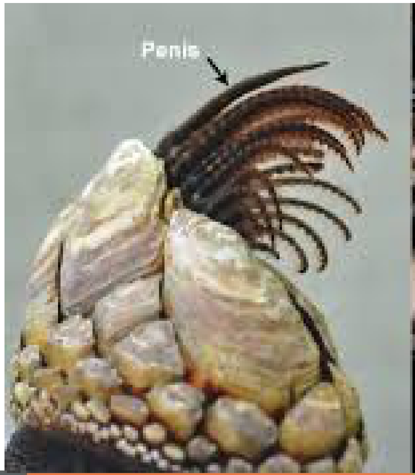
Class Cirripedia (barnacles)



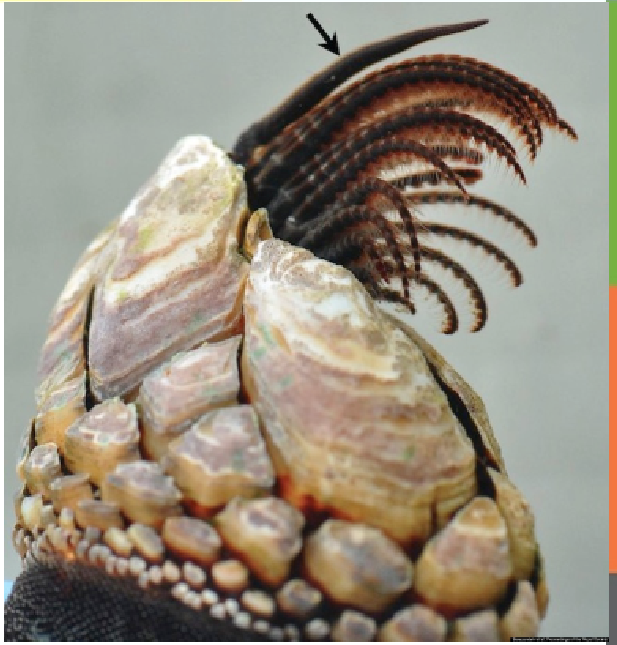
Adults are *sessile* and attach directly (acorn barnacles) or by a stalk (goose barnacles)

Head is reduced, abdomen is absent, and thoracic legs are long with hairlike setae

Jointed cirri bear setae and extend from the plates to feed on small particles



Barnacles



BARNACLES

SUB- PHYLUM HEXAPODA
THE INSECTS

Number of species identified: > 1,000,000. Most speciose animal taxon. Estimates of # of species vary from 2-30 million.

Freshwater, terrestrial, parasitic, aerial, but largely NOT marine. From a human perspective, astounding importance and impact. The study of insects is ENTOMOLOGY.

- Subphylum **Hexapoda**
  - **Wings** crucial to success – outgrowths of **body wall**
  - **~ 35 orders** – differences in wings, mouthparts and other structures
  - Separate sexes with internal fertilization
  - **Metamorphosis**
    - Complete – 4 stages, adult and larval stages very different
    - Incomplete – 3+ stages, young resemble miniature adults

Classification of Medically Important Arthropods

Class Insecta

Lice (blood)

- **Head louse**
  Pediculus humanus var. *capitis*
  pediculosis
- **Body louse**
  Pediculus humanus var. *corporis*
  pediculosis,
  epidemic typhus (*Rickettsia prowazekii*),
  trench fever (*Bartonella quintana*),
  relapsing fever (*Borrelia recurrentis*).
- **Pubic/Crab louse**
  Phthirus pubis
  pediculosis,
  sexually transmitted (pubic/perineal /eyelash/armpit hairs)

Fleas (blood)

- **Oriental/tropical rat flea**
  Xenopsylla cheopis
  plague (*Yersinia pestis*),
  endemic typhus (*Rickettsia typhi*),
  host of *Hymenolepis* tapeworms (H. nana – dwarf, H. diminuta – rat).
- **Northern rat flea**
  Nosopsyllus fasciatus
  endemic typhus (*Rickettsia typhi*).
- **Human flea**
  Pulex irritans
  skin irritation - female fleas burrows into human skin for laying eggs,
  intermediate host of *Hymenolepis* & *Dipylidium* tapeworm larvae, ?plague.

Transmission of Plague from fleas:
flea is infected with *Y. pestis* → bacteria obstruct the oesophagus of the flea → when flea draw blood from rat/human → cannot swallow → regurgitate blood with *Y. pestis*

Bugs (blood)

- **Bed bug**
  Cimex lectularius
  Cimex hemipterus
  allergy,
  II^ry bac. infection.
- **Reduviid bug** (Family Reduviidae)
  Rhodnius, Triatoma (kissing bugs), *Panstrongylus.*
  American trypanosomiasis (Chagas' disease) (*Trypanosoma cruzi*).

Transmission from Reduviid bugs:
Reduviid bugs defecate while feeding → faeces contain trypanosoma → scratching → spread of faeces around site of bite → trypanosoma enter through site of bite.

Flies (blood) –except 1

- **Sandfly** –slender long legs, erect wings on resting
  Phlebotomus – old world sandfly
  Lutzomyia – new world sandfly
  leishmaniasis,
  bartonellosis,
  sandfly fever – a viral disease like flu
- **Black fly/Buffalo gnats** hunchbacked appearance
  Simulium
  Onchocerciasis/river blindness (*Onchocerca volvulus*) – not in Sri Lanka.
- **Tsetse fly**
  Glossina
  African Trypanosomiasis (Sleeping sickness) (*Trypanosoma brucei* – *T.b. rhodesiense, T.b. gambiense*)
- **Deer fly/Yellow fly**
  Chrysops
  Loiasis (*Loa loa*),
  Tularaemia (*Francisella tularensis*).
- **Domestic fly** (non-blood)
  Musca domestica
  mechanical vector – transmits several viral Bacterial & parasitic diseases (swallow & regurgitate manner) – Ascariasis, Amoebiasis, myiasis.

Mosquitoes (blood)

Anopheline

- *Anopheles culicifacies*
  clear, stagnant/sluggishly moving water (drying river banks, gem pits, rock pools)
  rest at an angle to the resting surface.
  Malaria.

Culicine

Culex

Filarial

- *Culex quinquefasciatus*
  polluted, stagnant water
  Lymphatic filariasis (*Wuchereria bancrofti*).

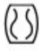
J.E.

- *Culex gelidus*
  husk pits
- *Culex tritaeniorhynchus*
- *Culex fuscocephala*
  paddy fields

Japanese Encephalitis.

Aedes

– dusk & dawn biters



- *Aedes aegypti*
  urban vector
  man-made small collections of clear water (tires, tins, plastic/glass containers, flower vases, blocked drains etc.)

- *Aedes albopictus*
  rural vector
  small collections of natural, clear water (tree stumps, leaves etc.)

Dengue (DF & DHF),
Yellow fever,
Chikungunya.

Mansonia

- *Mansonia spp.*
  rural vector
  breeds on the undersurface of water plants (eg: *Salvinia*)
  Brugian filariasis (*Brugia malayi*)
  Transmits *Dirofilaria repens* (a filarial nematode).

Class Arachnida

Ticks (blood)

- **Soft Ticks (Family Argasidae)**
  Argus spp.
  Allergic reactions;
  Tick paralysis – in animals & humans;
  Viral – Colorado tick fever, Crimean-Congo fever;
  Bacterial – Rocky mountain spotted fever, tick borne typhus, Q fever;
  Parasitic – Babesiosis.
- **Hard Ticks (Family Ixodidae)**
  Ixodes sp..
  all disease under soft ticks,
  Lyme disease (*Borrelia burgdorferi*).

Mites

- **Itch mite**
  Sarcoptes scabiei
  Scabies.
- **Chiggers/Red "bugs"**
  Trombicula larva
  scrub typhus (*Orientia tsutsugamushi*),
  irritating dermatitis.
- **House dust mite**
  Dermatophagoides pteronyssinus (European house dust mite)
  Dermatophagoides farinae (American house dust mite)
  Euroglyphus maynei
  Asthma & allergic symptoms.
  their gut contains potent digestive enzymes (notably proteases) that persist in their feces and are major inducers of allergic reactions such as wheezing.
  their exoskeleton can also contribute to allergic reactions

Spiders & Scorpions

- ❖ mildly venomous
- ❖ local signs around bite wound
- ❖ rarely – severe reaction with extensive tissue necrosis

Other Classes

- **Class Crustacea**
  Cyclops
  Intermediate host of Guinea worm (*Dracunculus medinensis*)
  & fish tape worm (*Diphyllobothrium latum*)
  Fresh water crabs & Crayfishes
  Intermediate host of lung fluke (*Paragonimus westermani*)
  Lobsters
  Shrimps
- **Class Myriapoda**
  Centipedes
  non-fatal, painful swelling around site of "bite".

2008 A/L Batch – Repeat Campaign (IPD Module)

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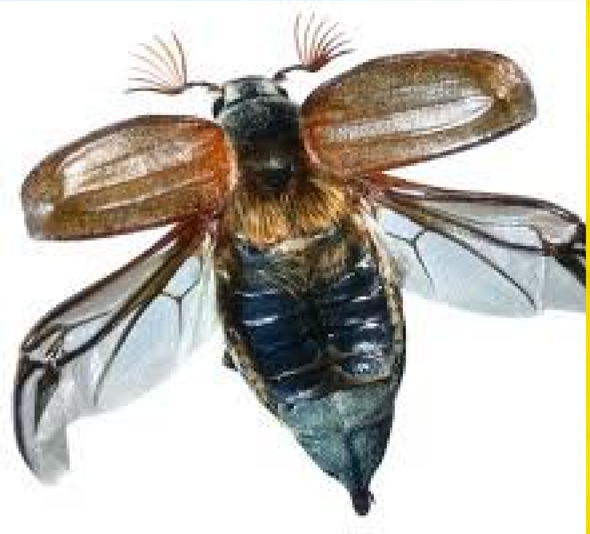
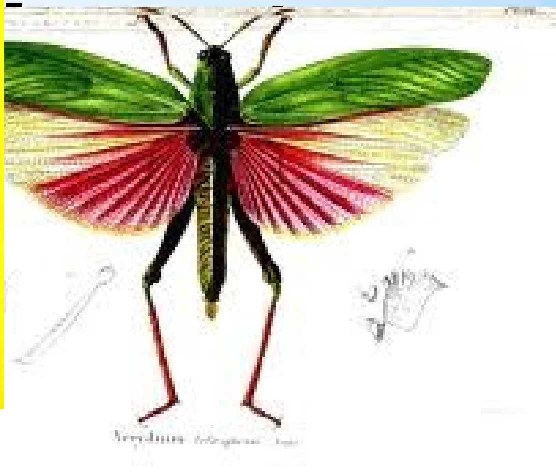
Wings and Flight

- Only invertebrates that fly
- 2 pairs of wings can be present, modified, or absent



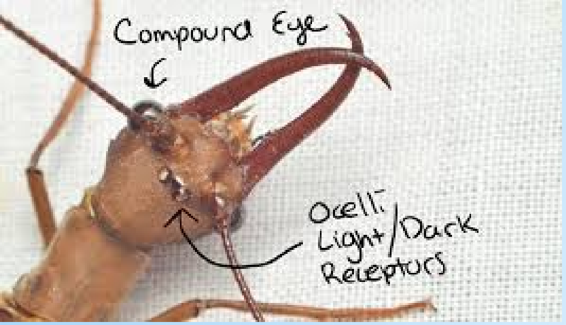


CHARACTERISTICS (IN ADDITION TO THE GENERAL ARTHROPOD CHARACTERISTICS)

- 3 body parts – *HEAD*, *THORAX*, *AND ABDOMEN*
- 3 pairs of legs, attached to the thorax.
- 2 pairs of wings (many exceptions), also attached to the thorax
- 1 pair of ANTENNAE
- 1 pair COMPOUND EYES
- Mouthparts highly variable, (but the typical condition is a pair of MANDIBLES, a pair of MAXILLAE, a LABRUM, and a HYPOPHARYNX.)
- Gaseous exchange via TRACHEAE, opening at SPIRACLES
- METAMORPHOSIS – *either:*

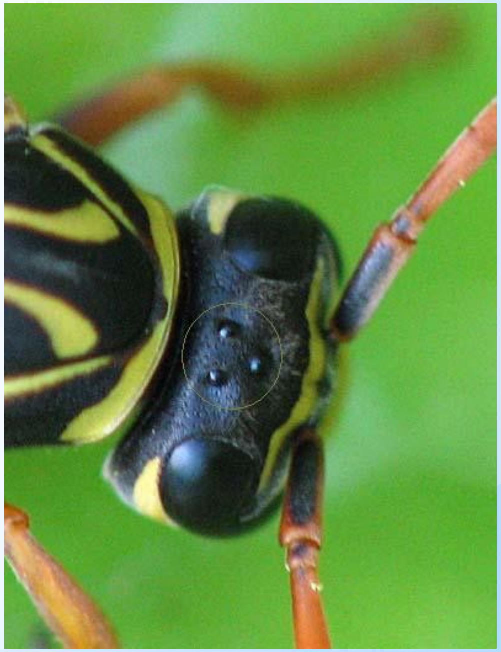
  HEMIMETOBOLY (incomplete) – egg, NYMPH(S), adult
- OR

  HOLOMETABOLY (complete) – egg, larva, pupa, adult



External Features

- Head
    - Compound eyes, pair of antennae, 3 ocelli



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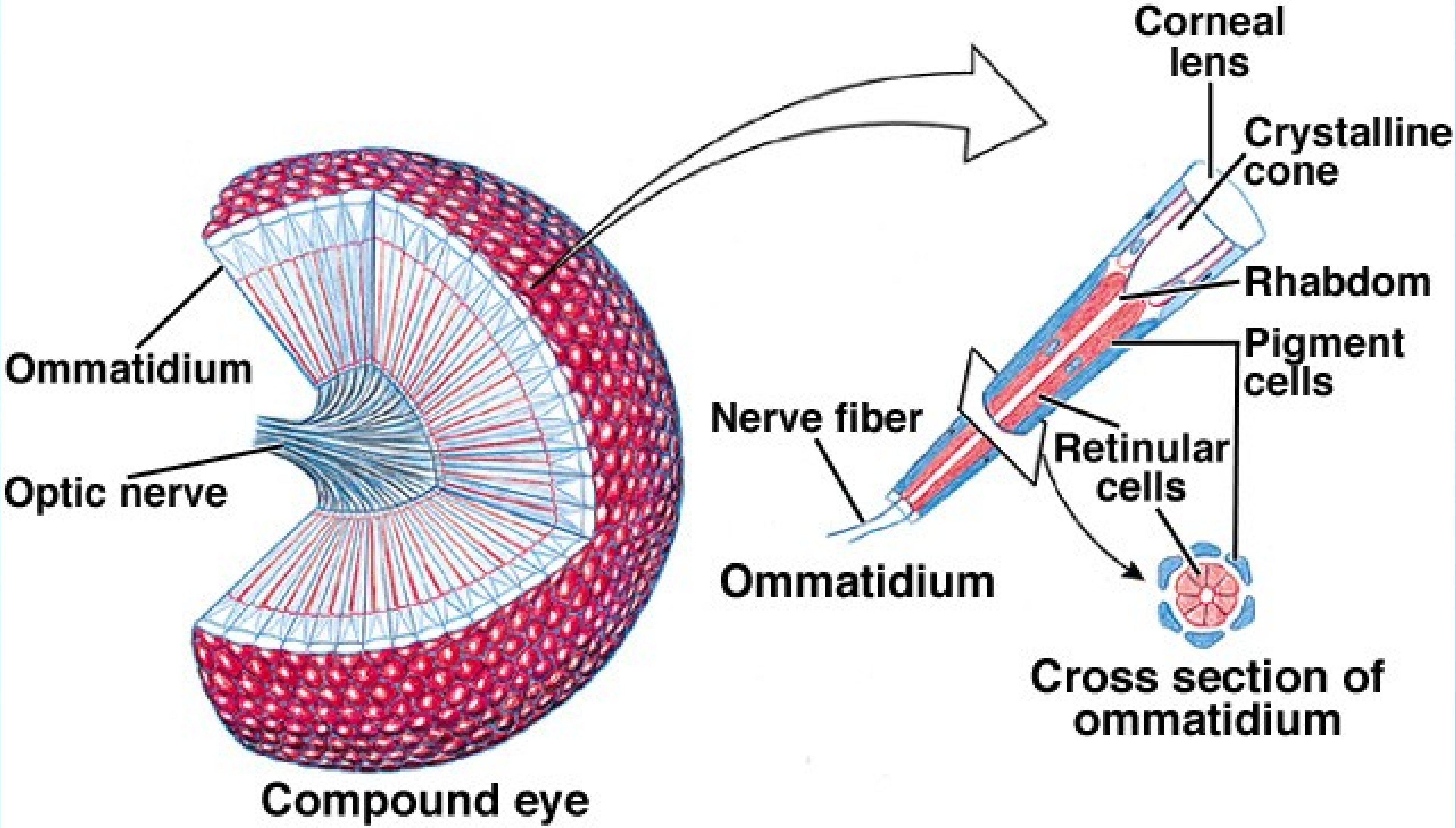
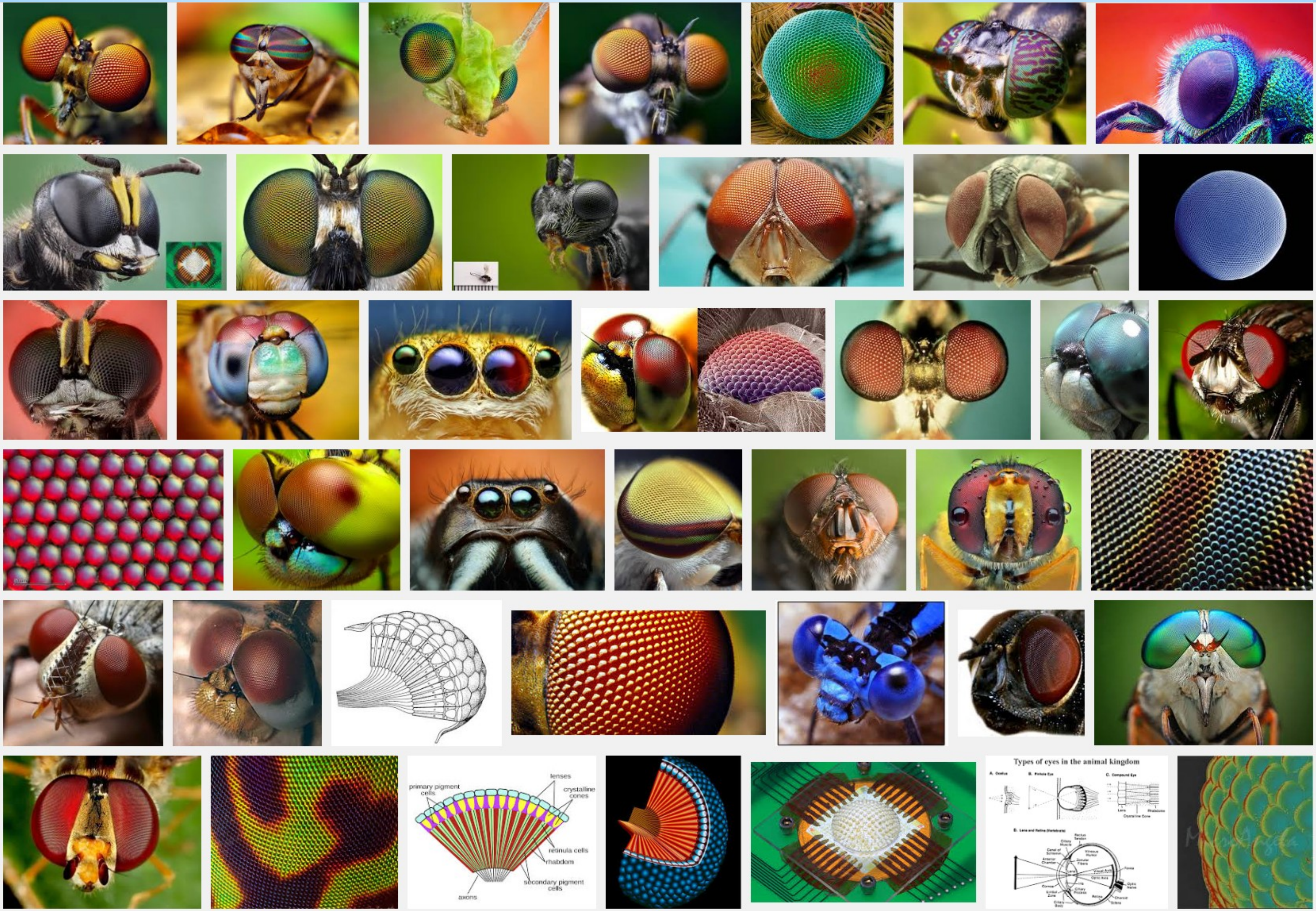
Compound eye of an insect




primary pigment cells
lenses
crystalline cones
retinula cells
rhabdom
secondary pigment cells
axons
Types of eyes in the animal kingdom
A. Ocellus
B. Pinhole Eye
C. Compound Eye
Lens
Rhabdome
Crystalline Cone
D. Lens and Retina (Vertebrate)
Rectus Tendon
Ciliary Muscle
Canal of Schlemm
Anterior Chamber
Vitreous Humor
Zonular Fibers
Fovea
Visual Axis
Optic Axis
Lens
Iris
Cornea
Optic Nerve
Limbal Zone
Ciliary Process
Retina
Choroid
Sclera
Ciliary Body

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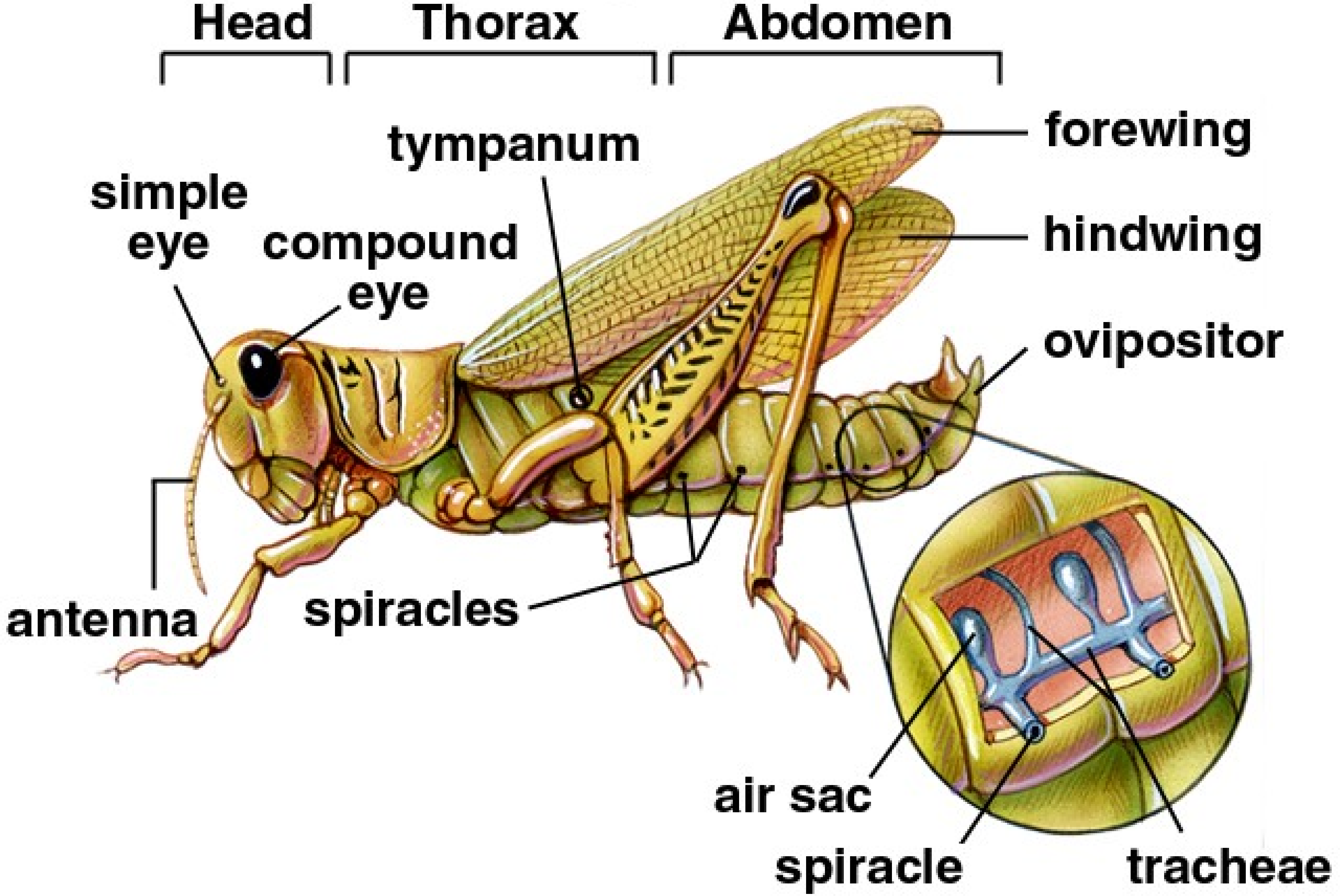
Female grasshopper



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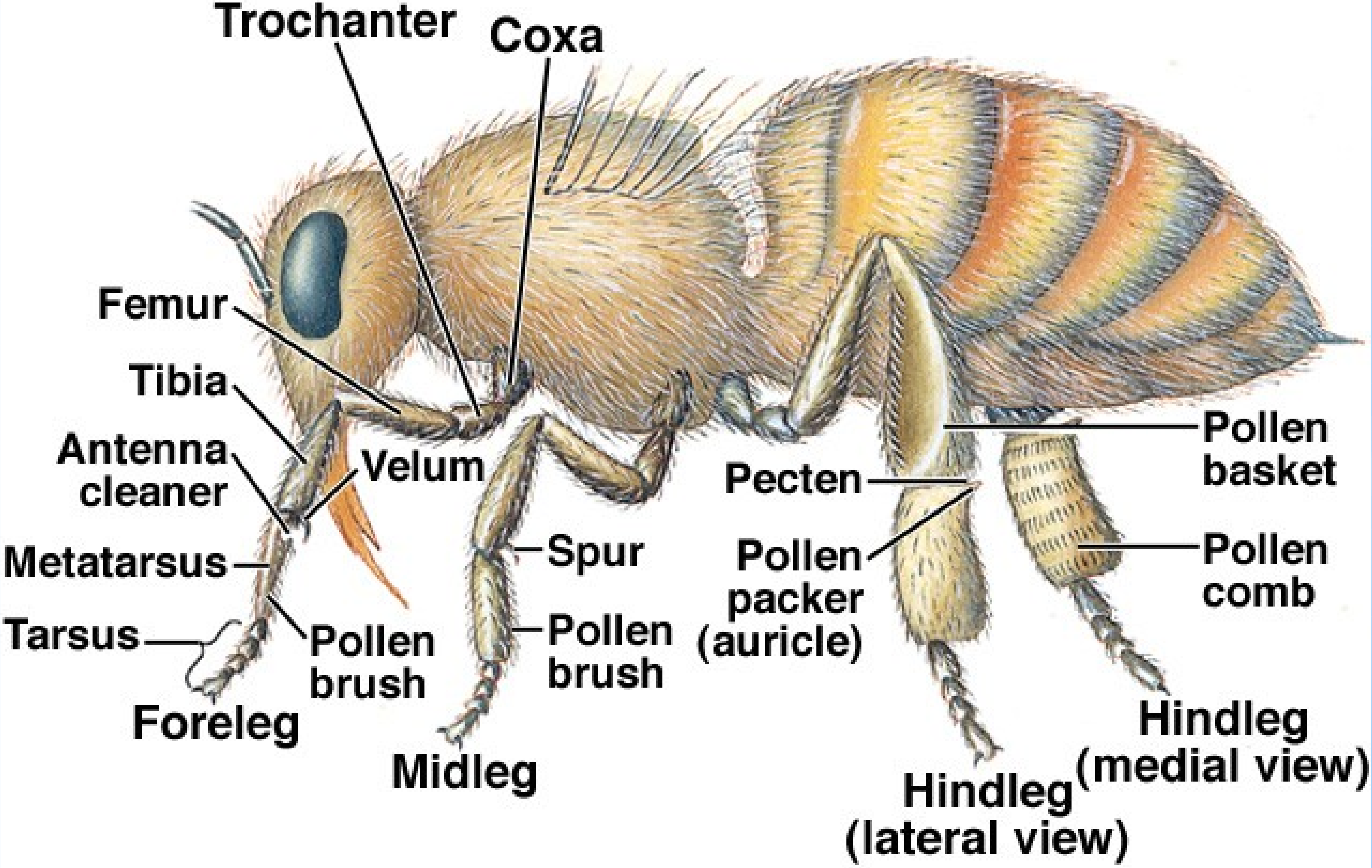
Adaptive legs of a worker honey bee



Mouthparts: labrum, mandibles, maxillae, labium, hypopharynx

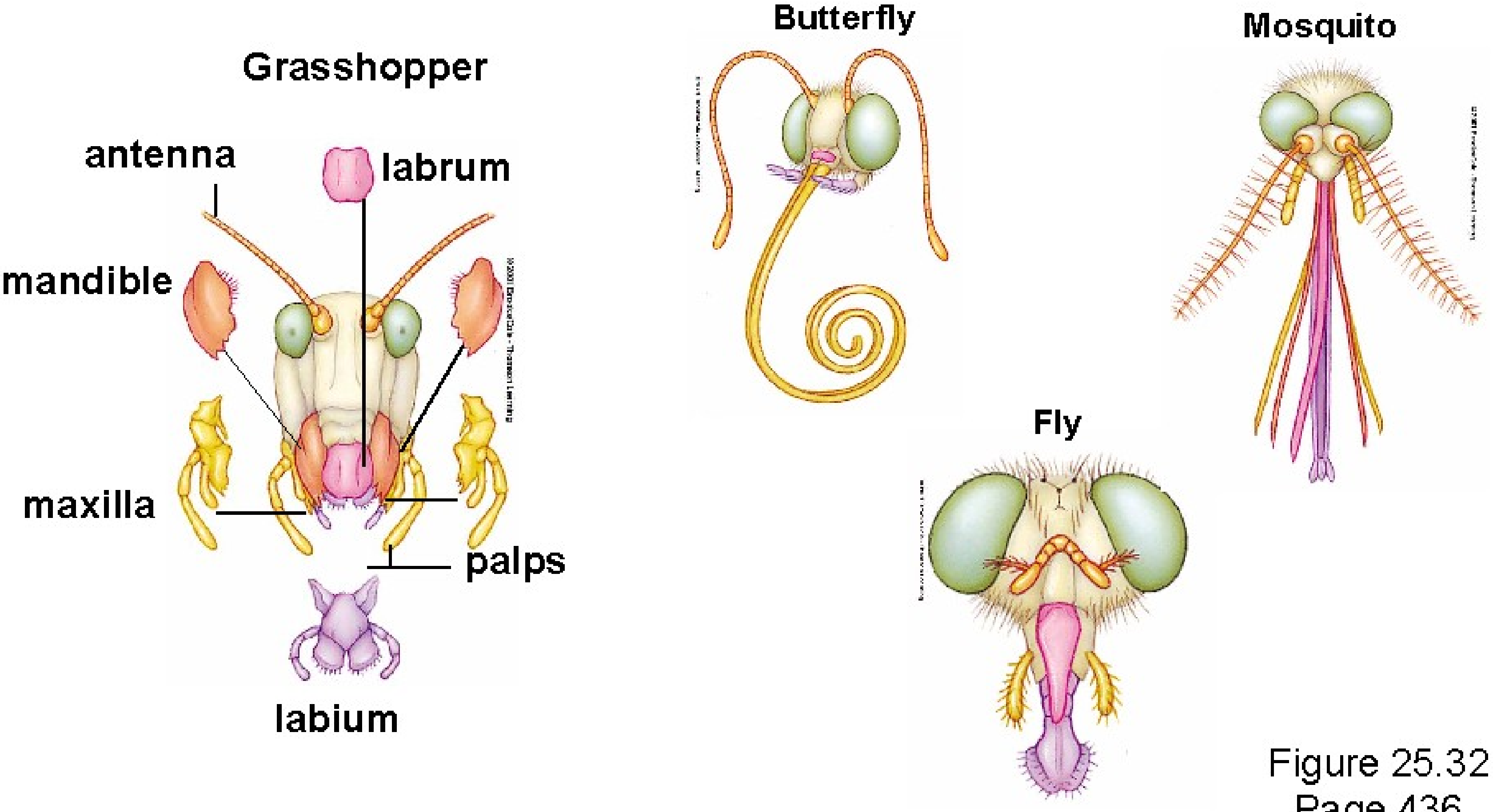


Figure 25.32
Page 436

Class Insecta

- Feeding
  - Determined by mouthparts- chewing or sucking (mosquito)
  - Some suck on plant juices or chew plant parts.
  - Some are scavengers, eating dead animals
  - Some are parasites (don’t kill their host)
  - Some are parasitoids (in this case the host dies)
  - Some are predators, eating other insects,
    - **Or even vertebrates!**

Mosquito feeding

Chewing with mandibles

Parasitoid

Praying mantis eating grasshopper (start at 1:00)

Ants eating vertebrate

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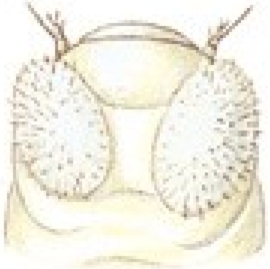
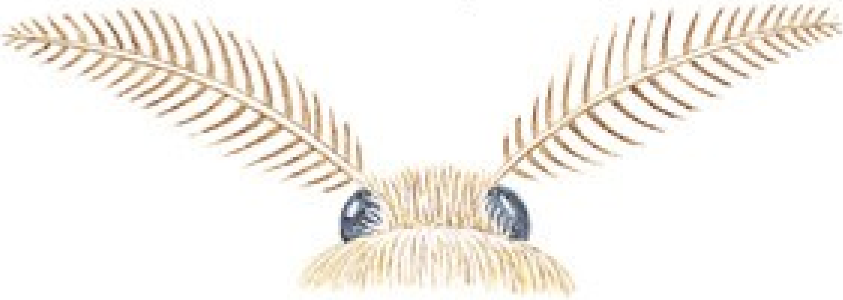
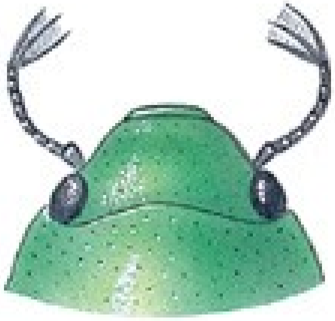
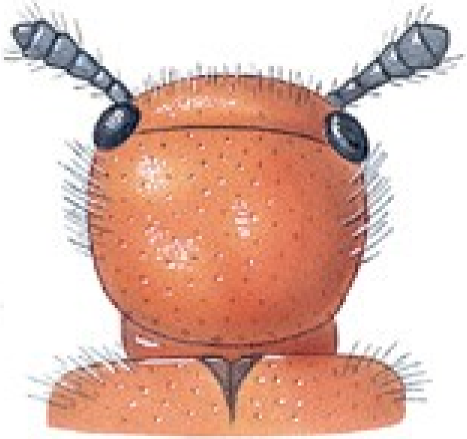
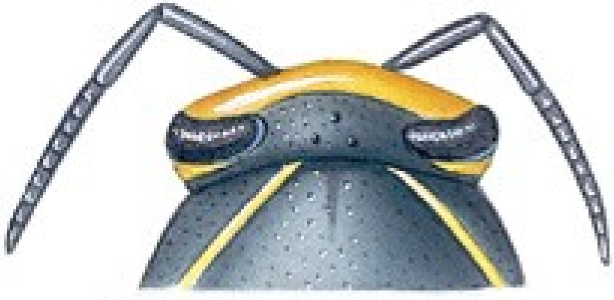
Types of insect antennae

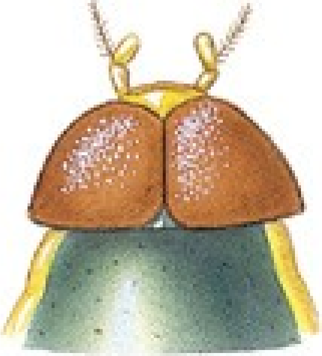

Silkworm larva


Silkworm moth


Japanese beetle


Checkered beetle

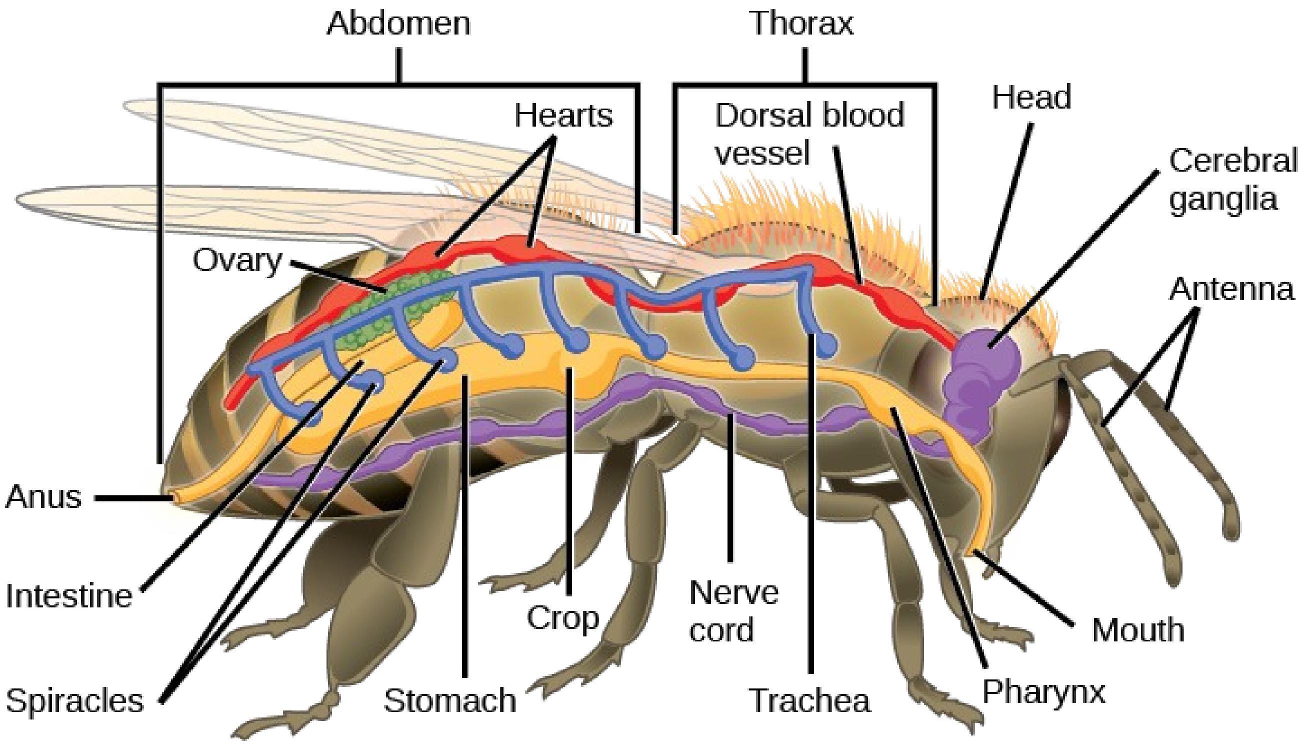

Yellow jacket


Syrphid fly

Class Insecta

- Nutrition
  - Digestive system:
    - Foregut: mouth, esophagus, crop
    - Midgut: stomach, gastric ceca
    - Hindgut: intestines, rectum, anus
    - Foregut and hindgut lined in cuticle and shed
    - Midgut does most of the absorption

Figure 28.36



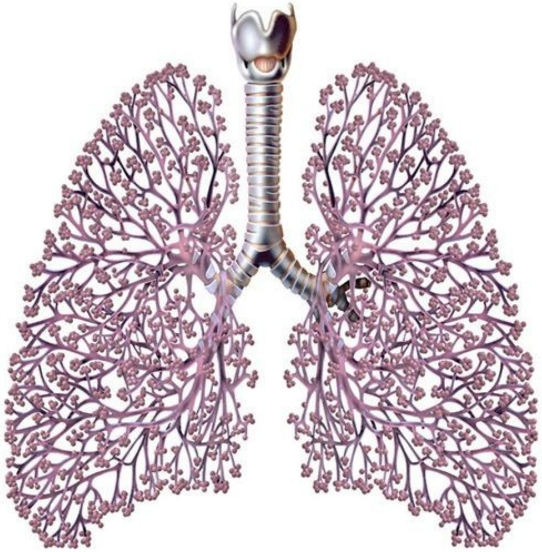
- In this basic anatomy of a hexapod insect, note that insects have a developed digestive system (yellow), a respiratory system (blue), a circulatory system (red), and a nervous system (purple).

Respiratory

Tracheal system directly to cells

Uses concentration gradient

Spiracles – tracheae tubes (cuticle)



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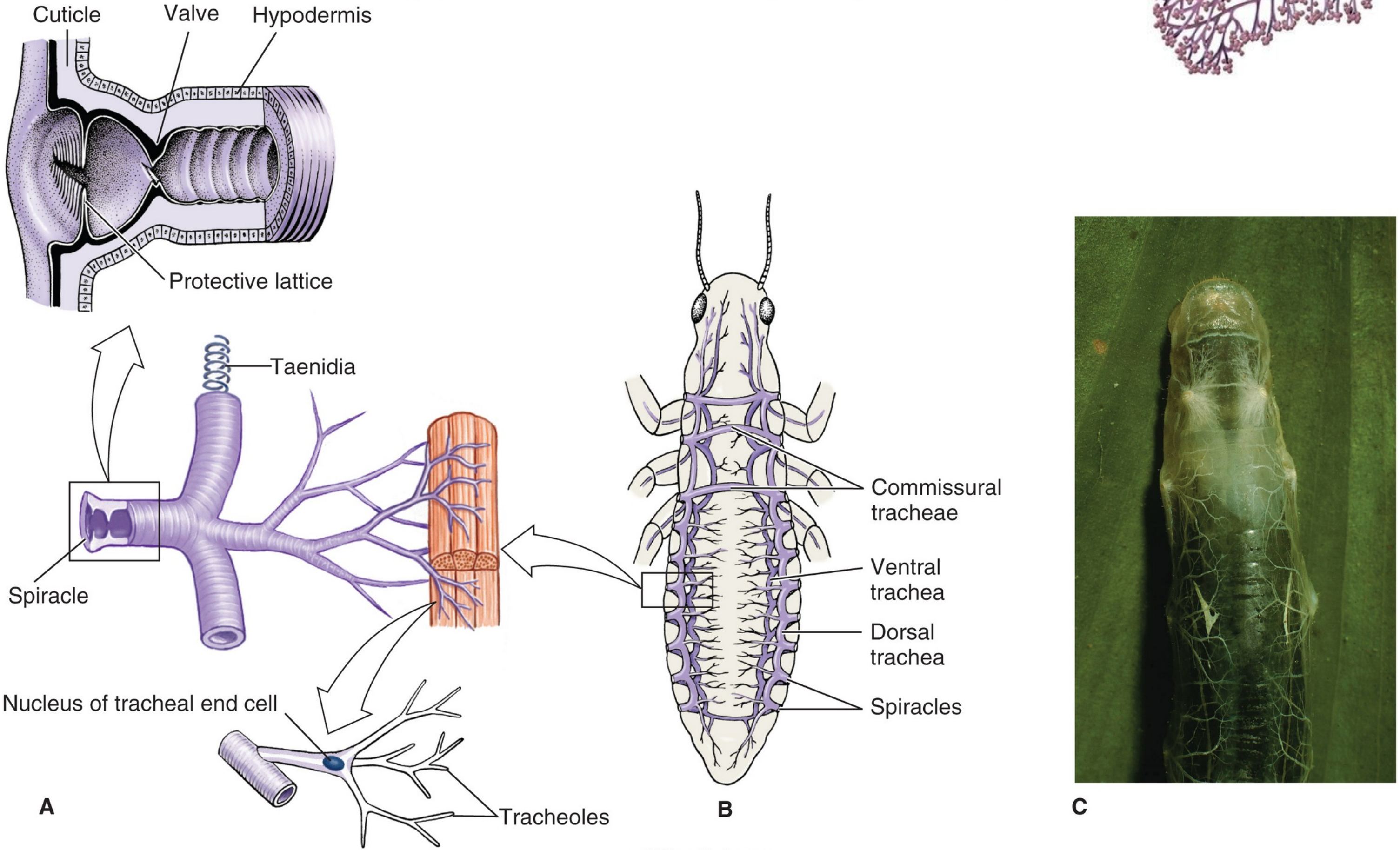

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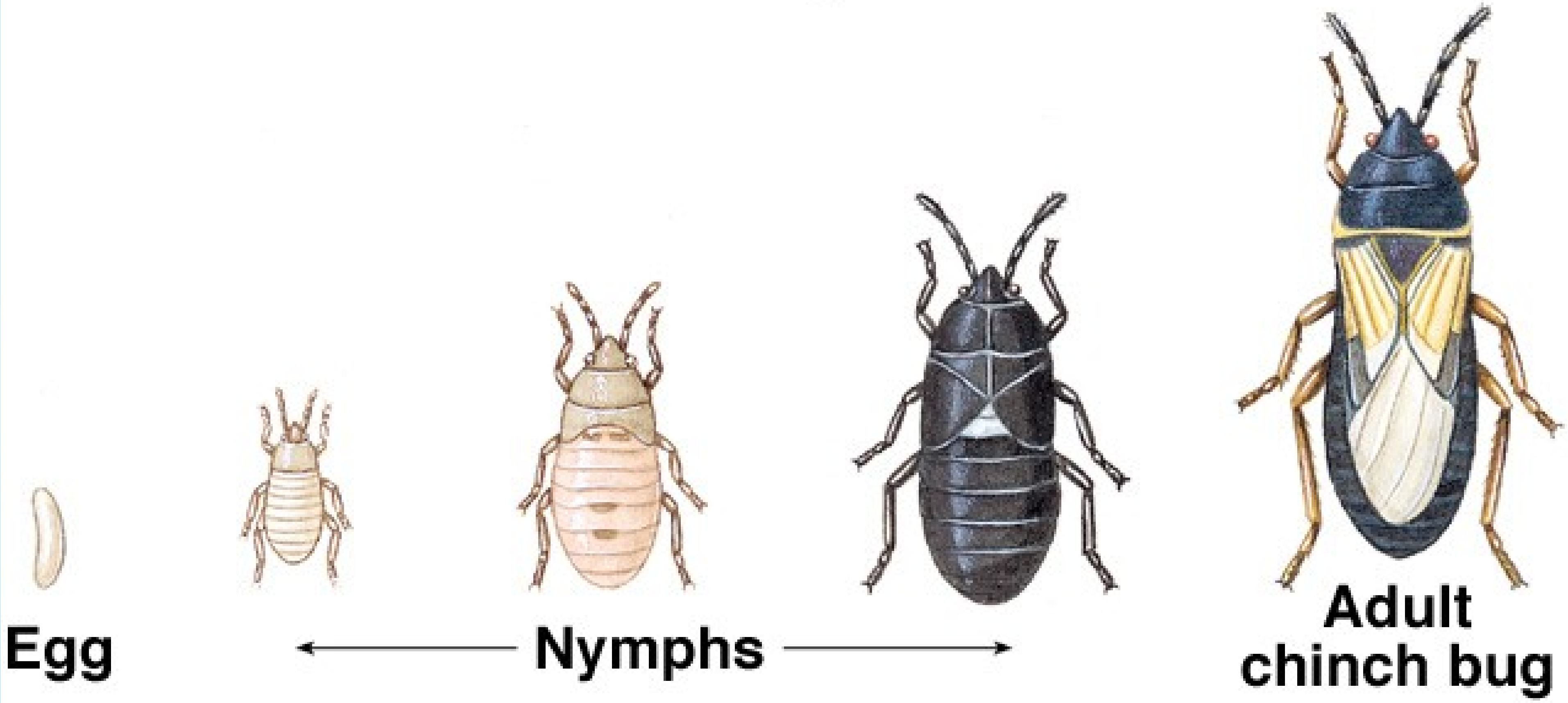
Hemimetabolous (incomplete) metamorphosis



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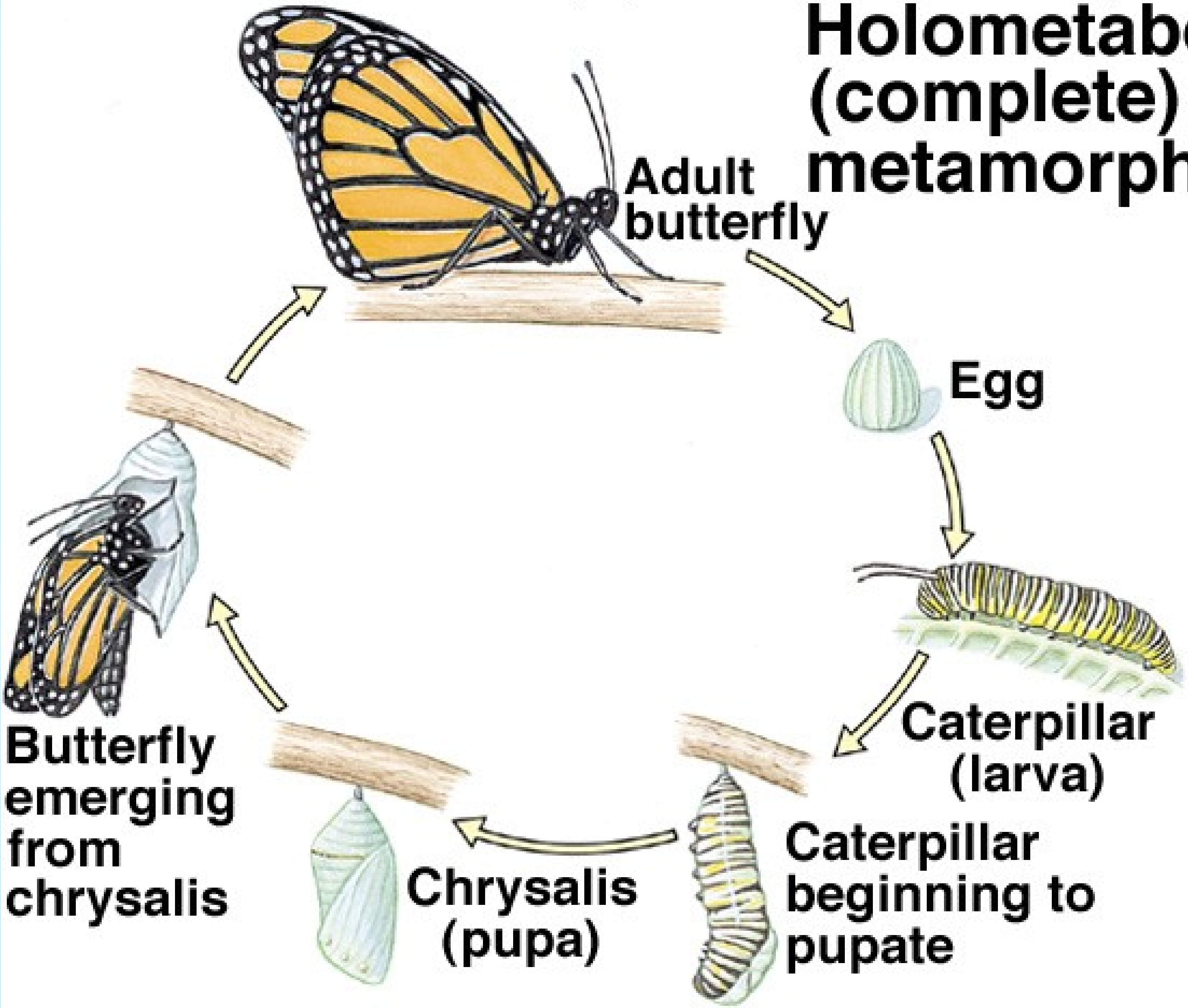
Holometabolous (complete) metamorphosis



Adult butterfly

Egg

Caterpillar (larva)

Caterpillar beginning to pupate

Chrysalis (pupa)

Butterfly emerging from chrysalis

Orders of Insects

Hemimetabolous

- Grasshoppers
- Dragonflies
- Roaches
- Termites
- True bugs
- Cicadas

Holometabolous

- Butterflies
- Beetles
- Flies and mosquitoes
- Bees
- Fleas

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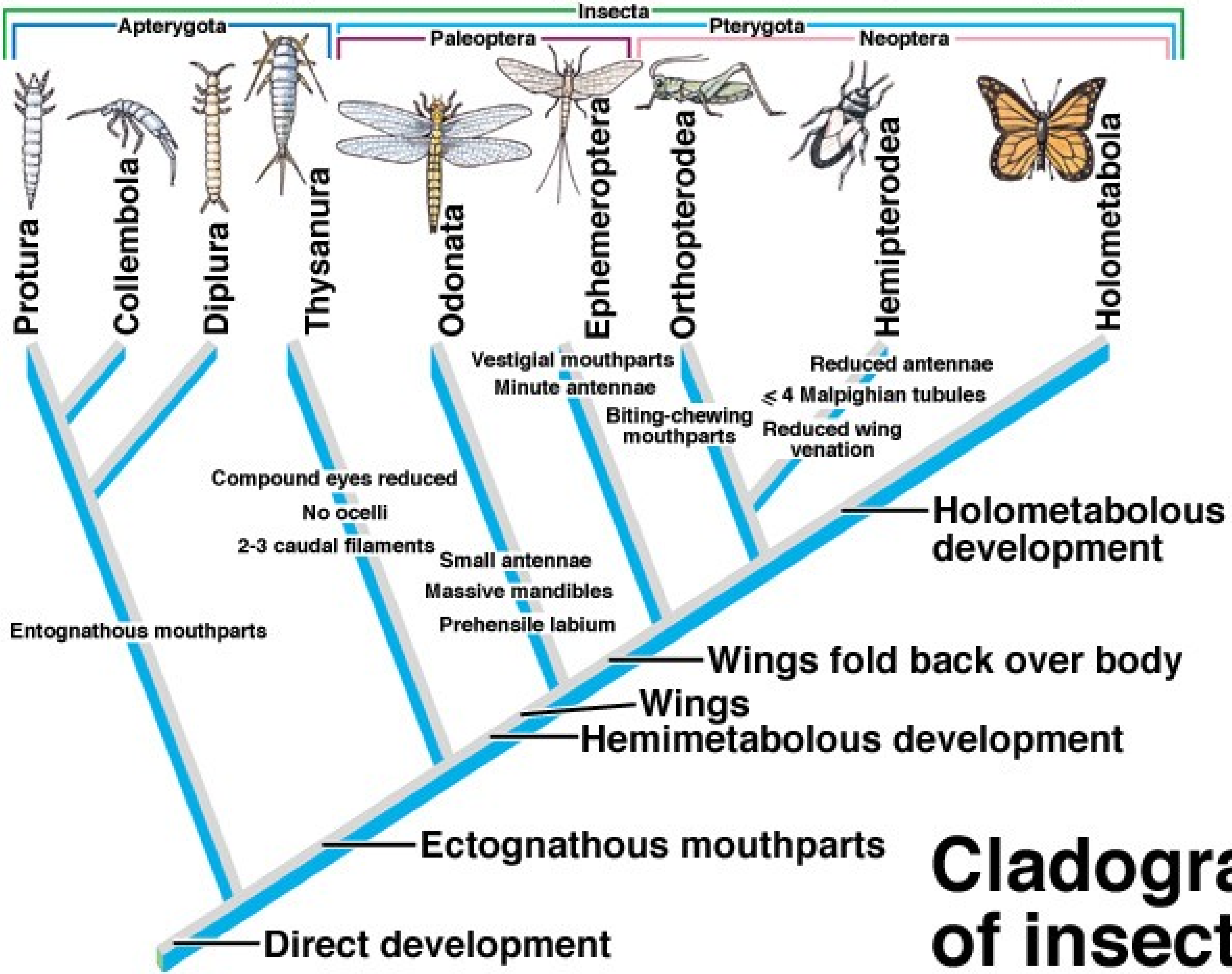


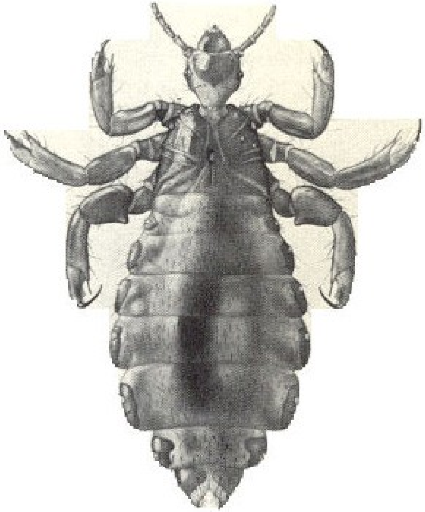
Cladogram of insecta

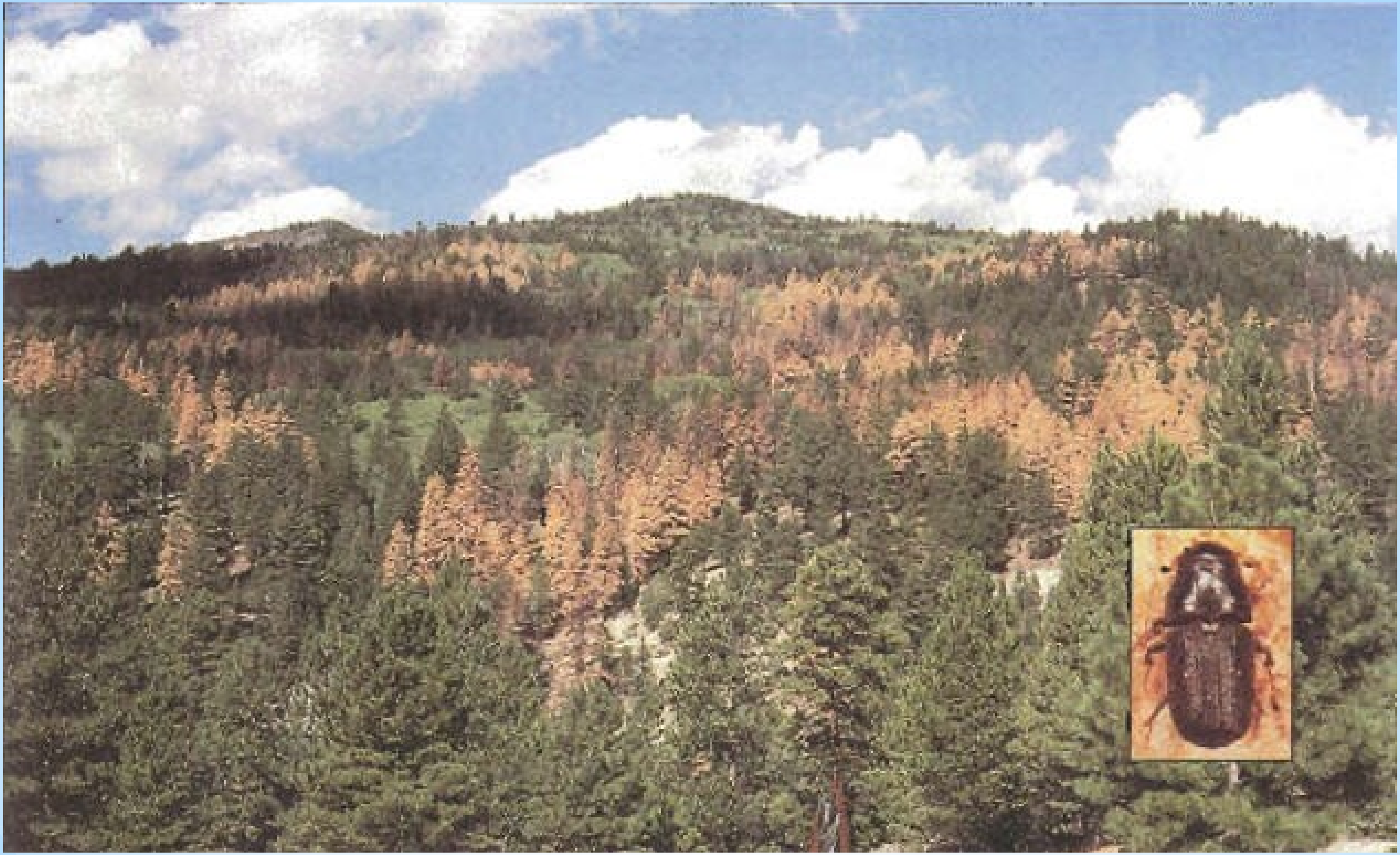
Lice:
Order Pthiraptera

DDT – insecticidal properties discovered in 1939 – used in WW II

Above, De-lousing with D.D.T. UNICEF, 1945.

Right. The female head louse *Pediculus humanus capitis.*





Bark beetle damage to Ponderosa Pine

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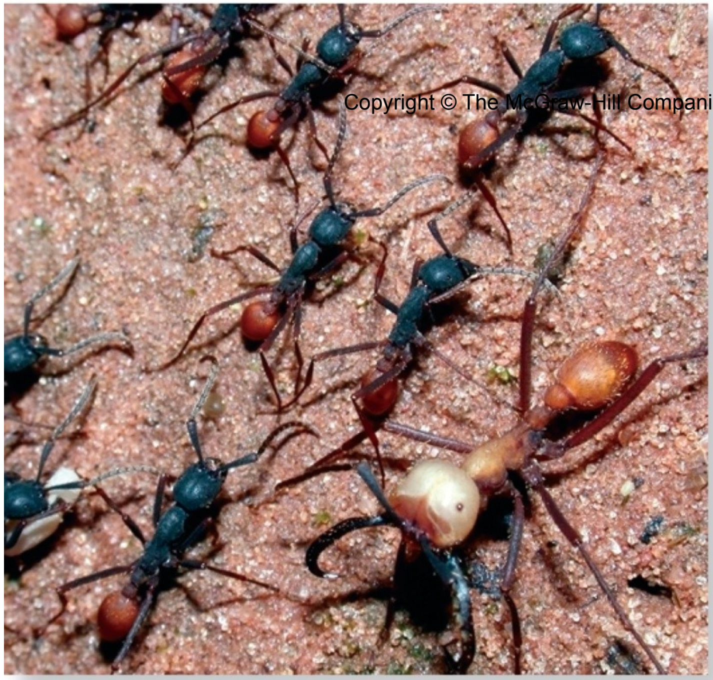
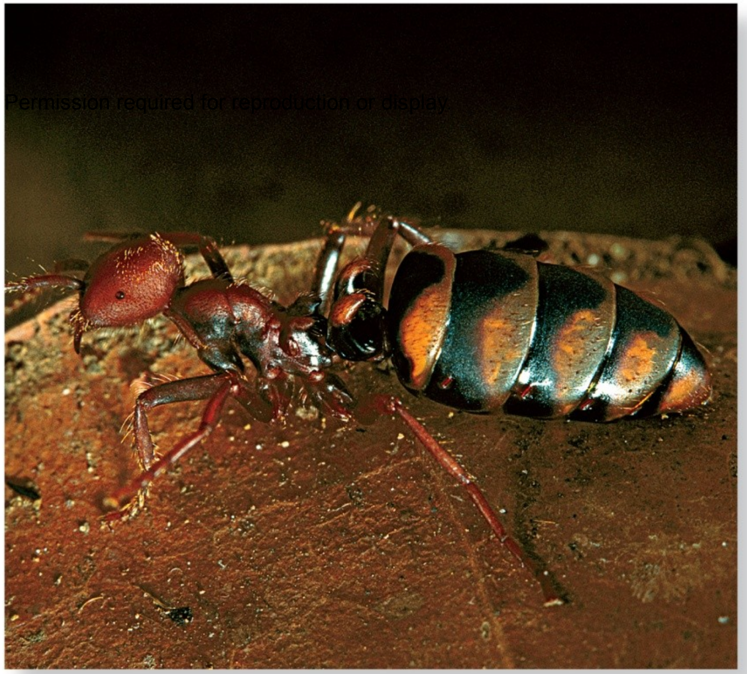


(a) Worker and soldier ants



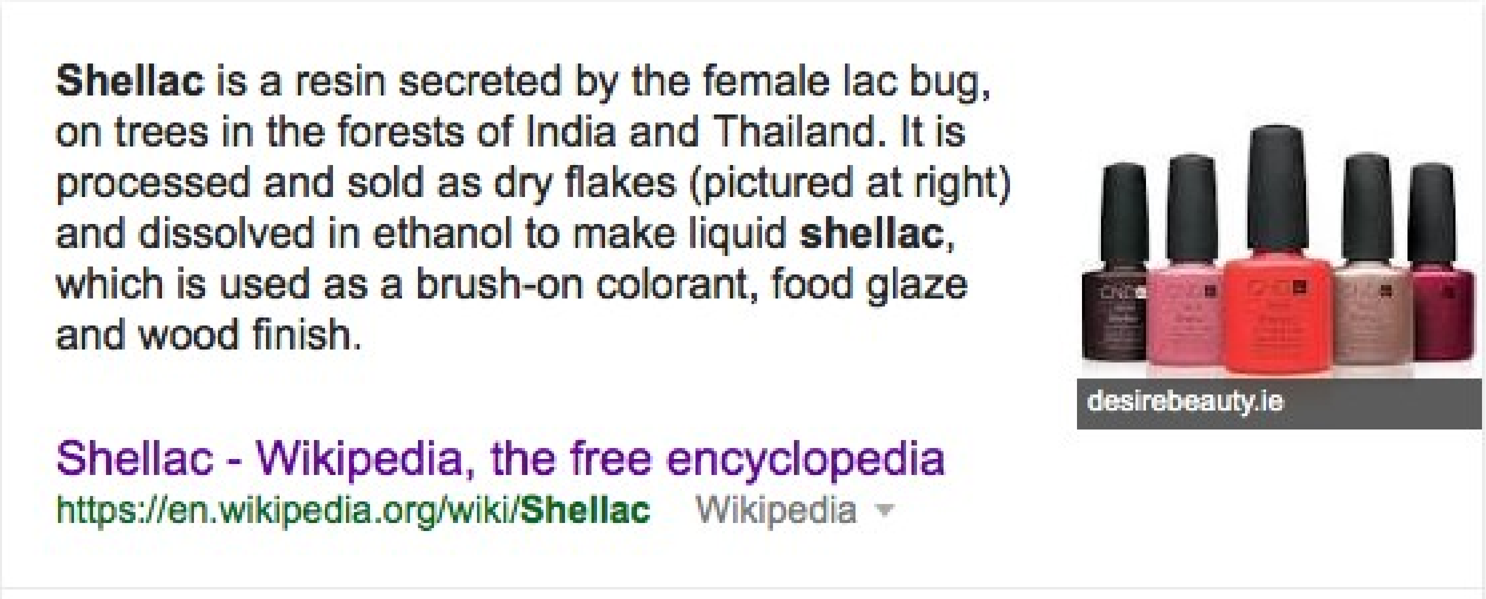
(b) Queen ant

a: © Alex Wild/myrmecos.net;b: © Christian Ziegler/MindenPictures/NationalGeographic Stock

Class Insecta

Insects and Human Welfare

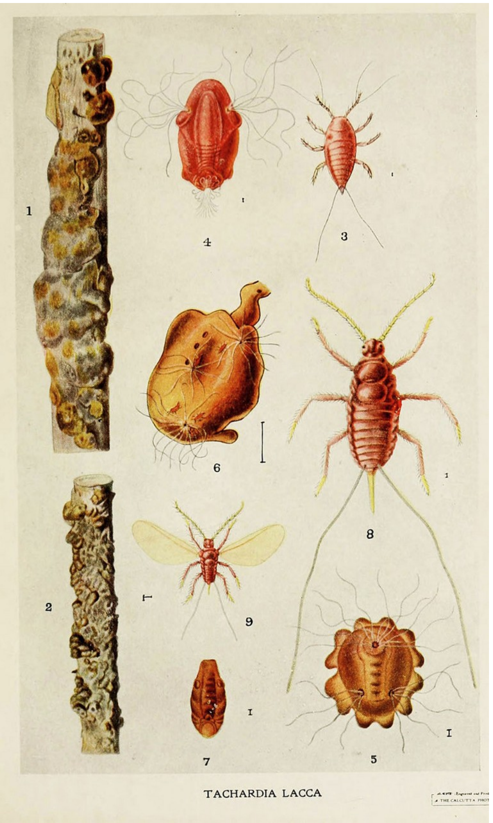
- Beneficial
  - Produce
    - Pollination of crops
    - Honey and beeswax
    - Silk
    - Shellac
  - Predators eat destructive insects
  - Clean up of dead material



Shellac is a resin secreted by the female lac bug, on trees in the forests of India and Thailand. It is processed and sold as dry flakes (pictured at right) and dissolved in ethanol to make liquid **shellac**, which is used as a brush-on colorant, food glaze and wood finish.

Shellac - Wikipedia, the free encyclopedia

https://en.wikipedia.org/wiki/**Shellac** Wikipedia



TACHARDIA LACCA

Class Insecta

Insects and Human Welfare

- Harmful
  - Destroy plants causing economic losses
  - Carriers of diseases
  - Blood-sucking or biting species
  - [Destruction of property](#)

Locust plagues

Class Insecta

Insects and Human Welfare

- Control
  - Chemical insecticides
  - Biological controls
    - Bacterial, viral, or fungal pathogens
    - Introduction of natural predators or parasite
    - Interfere with reproduction or behavior
  - Combination

Reported Agricultural Pesticide Use In Fresno County

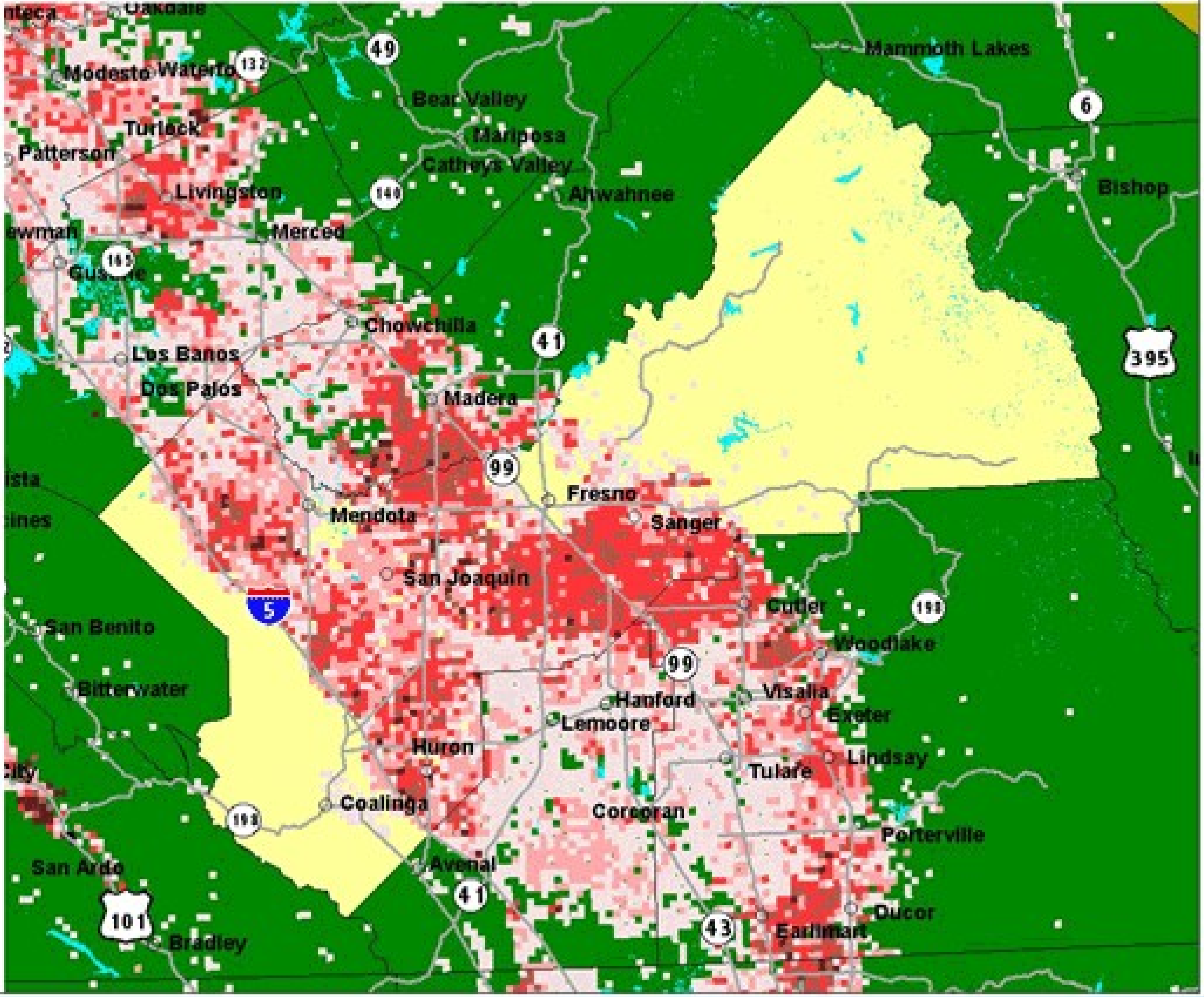
Total Pounds of Active Ingredient Applied Per Square Mile

Pesticide Action Network

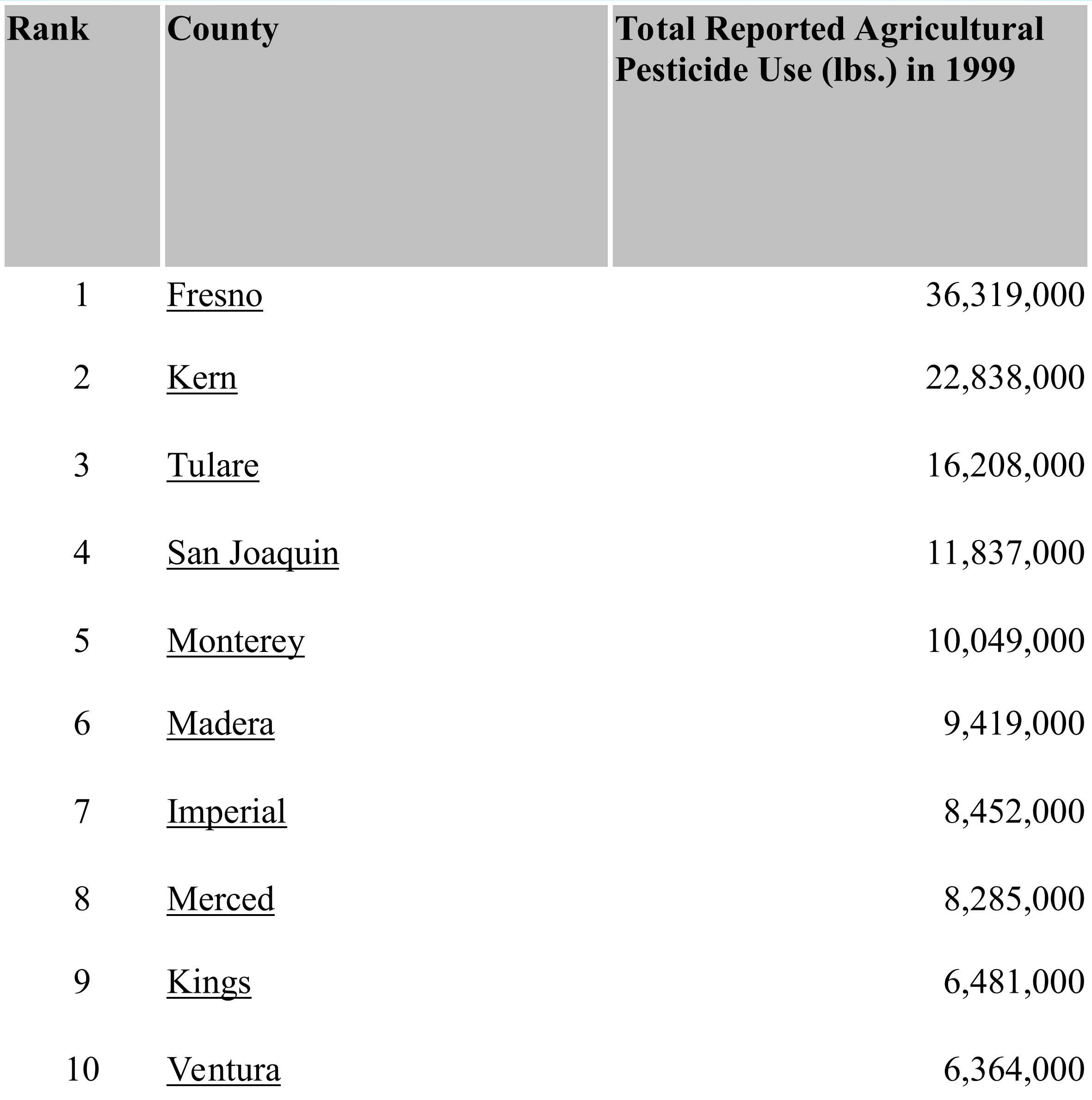
Pesticide Use
lbs / square mile

▫	1 - 5,000
🟥	5,001 - 15,000
🟥	15,001 - 35,000
🟫	35,001 - 60,000
🟫	60,001 - 180,000
⬛	> 200,000

- ╱╲╱ Highways
- 🟦 Water
- 🟨 Fresno County
- ○ Cities



Data Sources:
Cal. EPA DPR Pesticide Use Report 1999
Public Land Survey DPR 1999
Datamocracy Road, Water and County Coverages
Produced with ESRI ARCVIEW 3.2a software



Rank	County	Total Reported Agricultural Pesticide Use (lbs.) in 1999
1	Fresno	36,319,000
2	Kern	22,838,000
3	Tulare	16,208,000
4	San Joaquin	11,837,000
5	Monterey	10,049,000
6	Madera	9,419,000
7	Imperial	8,452,000
8	Merced	8,285,000
9	Kings	6,481,000
10	Ventura	6,364,000

Some Major orders of Insects

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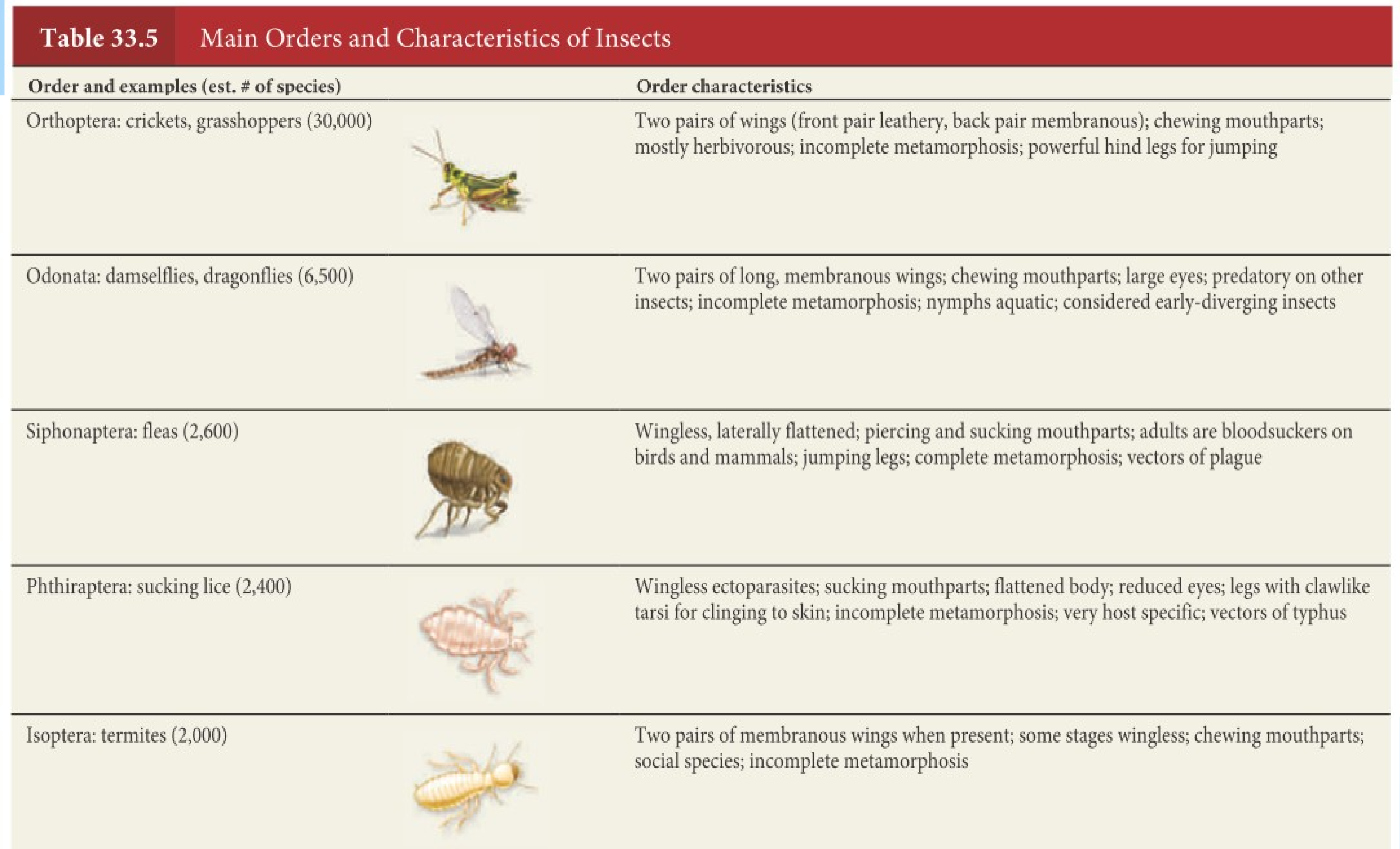

Table 33.5 Main Orders and Characteristics of Insects

Order and examples (est. # of species)	Order characteristics
Orthoptera: crickets, grasshoppers (30,000)	Two pairs of wings (front pair leathery, back pair membranous); chewing mouthparts; mostly herbivorous; incomplete metamorphosis; powerful hind legs for jumping
Odonata: damselflies, dragonflies (6,500)	Two pairs of long, membranous wings; chewing mouthparts; large eyes; predatory on other insects; incomplete metamorphosis; nymphs aquatic; considered early-diverging insects
Siphonaptera: fleas (2,600)	Wingless, laterally flattened; piercing and sucking mouthparts; adults are bloodsuckers on birds and mammals; jumping legs; complete metamorphosis; vectors of plague
Phthiraptera: sucking lice (2,400)	Wingless ectoparasites; sucking mouthparts; flattened body; reduced eyes; legs with clawlike tarsi for clinging to skin; incomplete metamorphosis; very host specific; vectors of typhus
Isoptera: termites (2,000)	Two pairs of membranous wings when present; some stages wingless; chewing mouthparts; social species; incomplete metamorphosis

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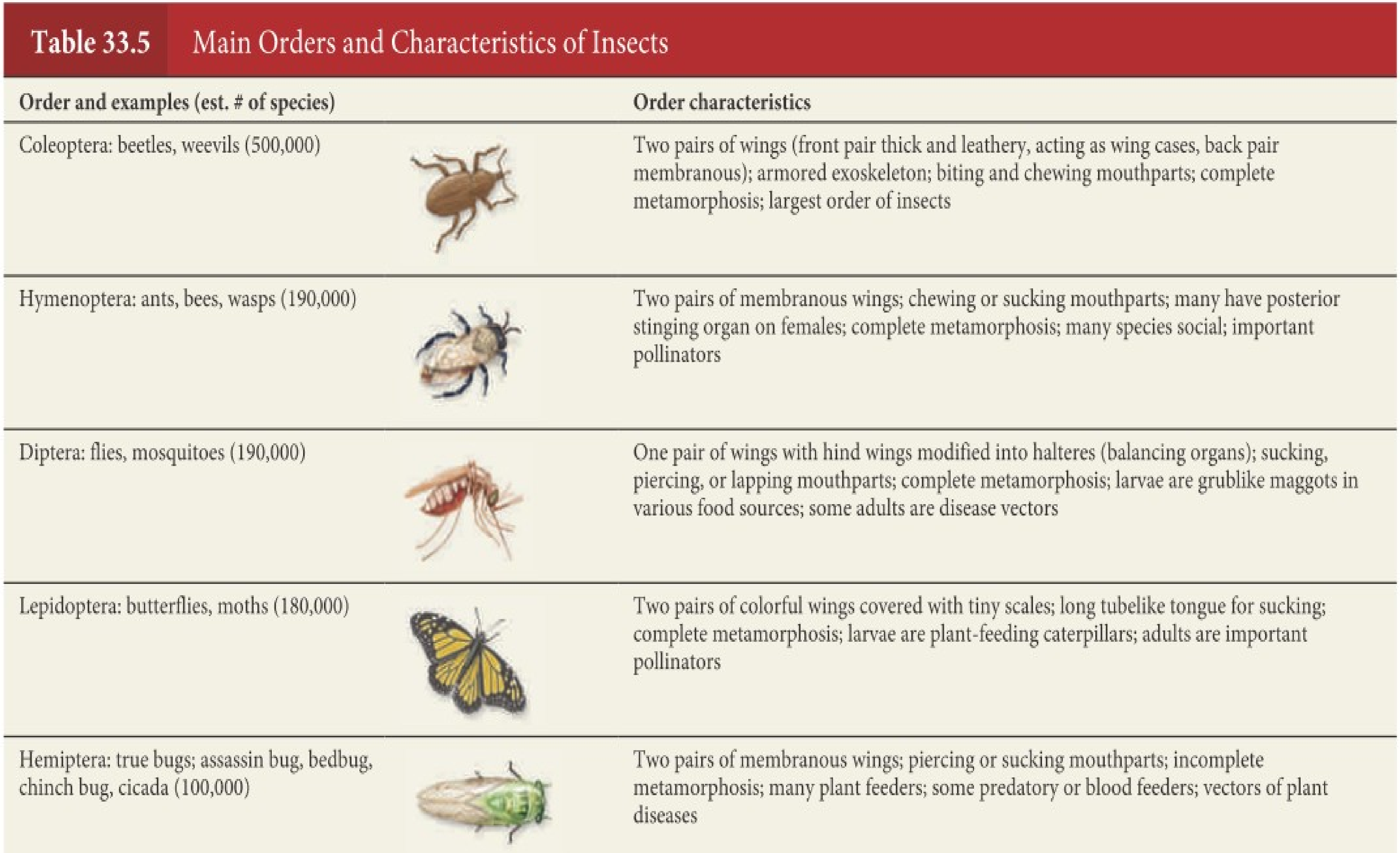

Table 33.5 Main Orders and Characteristics of Insects

Order and examples (est. # of species)	Order characteristics
Coleoptera: beetles, weevils (500,000)	Two pairs of wings (front pair thick and leathery, acting as wing cases, back pair membranous); armored exoskeleton; biting and chewing mouthparts; complete metamorphosis; largest order of insects
Hymenoptera: ants, bees, wasps (190,000)	Two pairs of membranous wings; chewing or sucking mouthparts; many have posterior stinging organ on females; complete metamorphosis; many species social; important pollinators
Diptera: flies, mosquitoes (190,000)	One pair of wings with hind wings modified into halteres (balancing organs); sucking, piercing, or lapping mouthparts; complete metamorphosis; larvae are grublike maggots in various food sources; some adults are disease vectors
Lepidoptera: butterflies, moths (180,000)	Two pairs of colorful wings covered with tiny scales; long tubelike tongue for sucking; complete metamorphosis; larvae are plant-feeding caterpillars; adults are important pollinators
Hemiptera: true bugs; assassin bug, bedbug, chinch bug, cicada (100,000)	Two pairs of membranous wings; piercing or sucking mouthparts; incomplete metamorphosis; many plant feeders; some predatory or blood feeders; vectors of plant diseases

Phylum Tardigrada

- Known as “water bears”
- Very small, less than 1 mm long
- About 900 live in a water film around mosses and lichens
- Most are terrestrial that occupy a film of water surrounding mosses and lichens
- Trunk bears eight short unjointed legs, each with claws
- A pair of *stylets and sucking pharynx* protrude to pierce nematodes or plant cells
- Body covered by cuticle that is molted four or more times during lifetime
- Most of the body cavity a *hemocoel* (small cavity that fills with blood.
- *No circulatory or respiratory systems*

Phylum Tardigrada

- *Cryptobiosis*
  - Terrestrial tardigrades can *suspend metabolism* to survive harsh conditions
  - Tardigrades can dehydrate from *85% water to only 3% water*
    - In this state they can resist extreme temperatures, ionizing radiation, oxygen deficiency, etc. for years
  - When water is available, they become metabolically active again

Phylum Tardigrada

- *Reproduction*
  - Sexes are *separate*
  - In parthenogenetic freshwater and moss-dwelling species, males are unknown

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Courtesy Diane R. Nelson

Tardigrades

- Little known about them.
- Can survive:
  - 300^{o}F degree temps
  - 460^{o}F degrees below zero
  - the vacuum of space
  - 1000 atmospheres of pressure
  - X-rays, ultraviolet radiation
  - Click “Tardigrades” above to watch short video

Deuterostomes

- **Phylum Echinodermata**
  - Modified secondary **penta**radial symmetry – 5 parts
    - Secondary because larvae are bilateral
  - Cephalization absent – no head
- **Phylum Hemichordata**
- **Phylum Chordata**

The Echinoderms – Phylum Echinodermata

Number of species identified: ~7,000 living, 20,000 fossil. One word for this group – WEIRD. They have a unique combination of characteristics totally unlike any other animal phylum.

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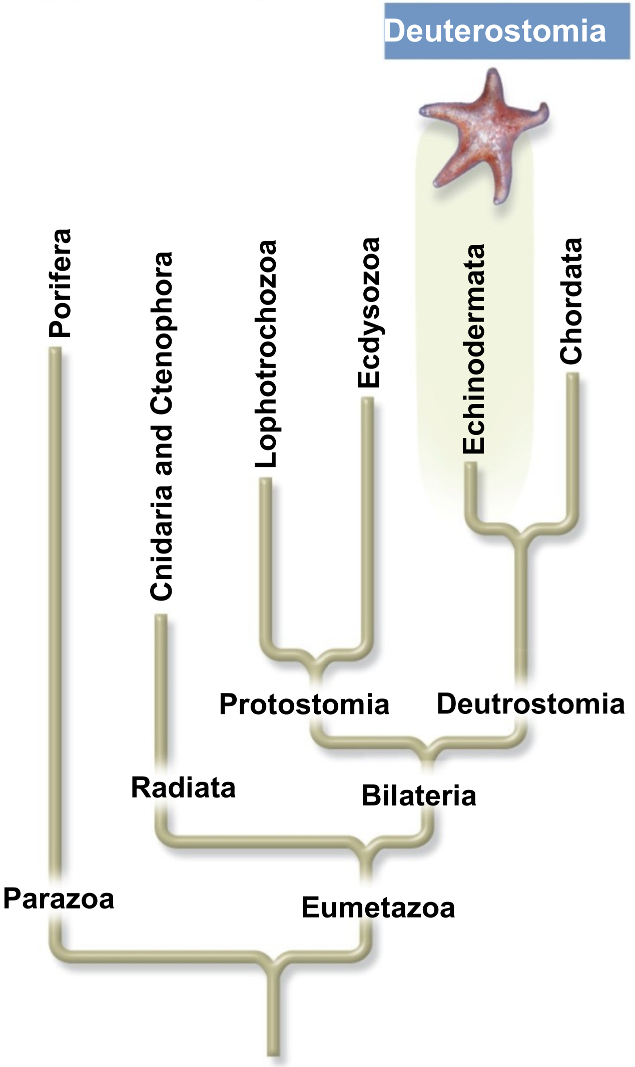

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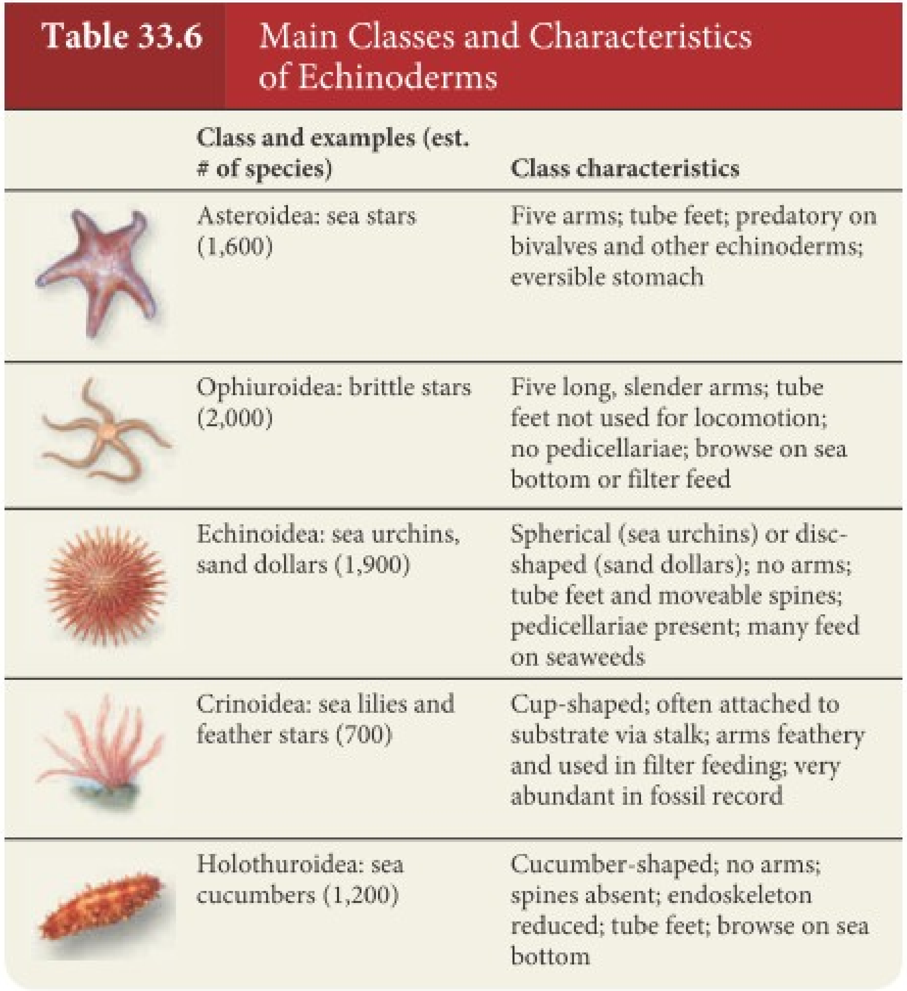
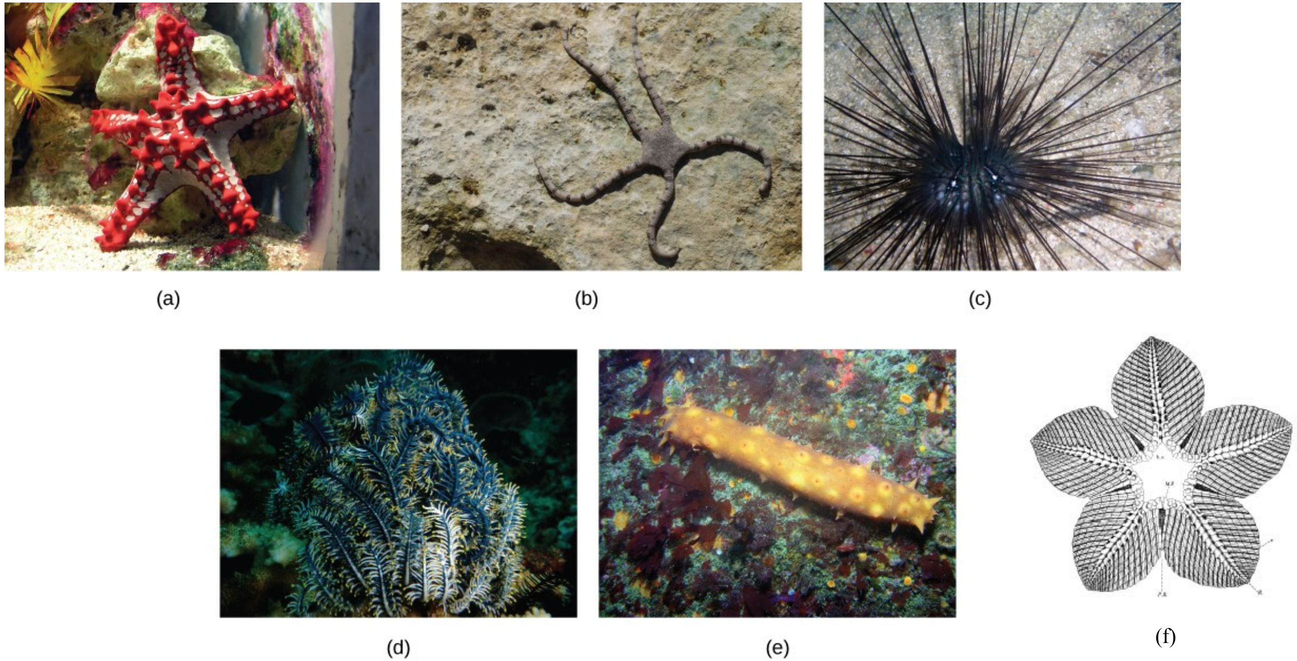


Table 33.6 Main Classes and Characteristics of Echinoderms

	Class and examples (est. # of species)	Class characteristics
	Asteroidea: sea stars (1,600)	Five arms; tube feet; predatory on bivalves and other echinoderms; eversible stomach
	Ophiuroidea: brittle stars (2,000)	Five long, slender arms; tube feet not used for locomotion; no pedicellariae; browse on sea bottom or filter feed
	Echinoidea: sea urchins, sand dollars (1,900)	Spherical (sea urchins) or disc-shaped (sand dollars); no arms; tube feet and moveable spines; pedicellariae present; many feed on seaweeds
	Crinoidea: sea lilies and feather stars (700)	Cup-shaped; often attached to substrate via stalk; arms feathery and used in filter feeding; very abundant in fossil record
	Holothuroidea: sea cucumbers (1,200)	Cucumber-shaped; no arms; spines absent; endoskeleton reduced; tube feet; browse on sea bottom

Figure 28.45


(a) (b) (c)

(d) (e) (f)

- Different members of Echinodermata include the (a) sea star of class Asteroidea, (b) the brittle star of class Ophiuroidea, (c) the sea urchins of class Echinoidea, (d) the sea lilies belonging to class Crinoidea, and (e) sea cucumbers, representing class Holothuroidea, (f) extinct subclass of asterozoan from about 500 mya
- (credit a: modification of work by Adrian Pingstone; credit b: modification of work by Joshua Ganderson; credit c: modification of work by Samuel Chow; credit d: modification of work by Sarah Depper; credit e: modification of work by Ed Bierman; credit f: Tree of Life web project)

CLASS CRINOIDEA – crinoids (sea lilies and feather stars): *Antedon*

CLASS ASTEROIDEA – sea stars or starfish:

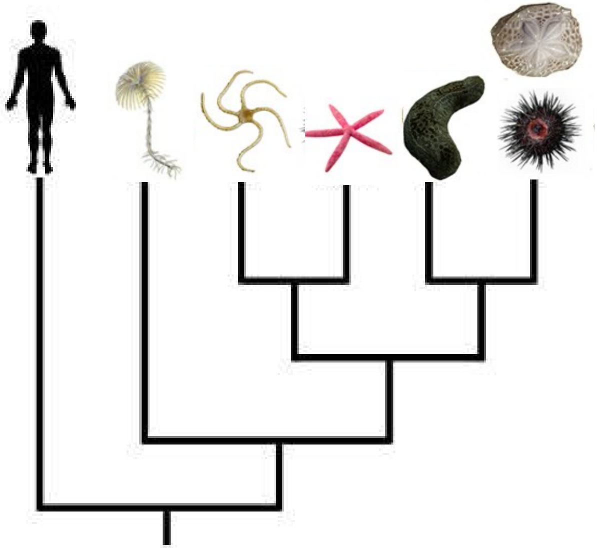
Pisaster, Asterias

CLASS OPHIUROIDEA – brittle stars: *Ophi*

CLASS ECHINOIDEA – sea urchins and sa dollars:

Strongylocentrotus

CLASS HOLOTHUROIDEA – sea cucumbers: *Cucumaria*



Asteroidea: Sea Stars: Characteristics

- Open ambulacral grooves
- Pedicellariae present
- Tube feet on oral side
- Anus and madeporite aboral
- Top predator in its environment

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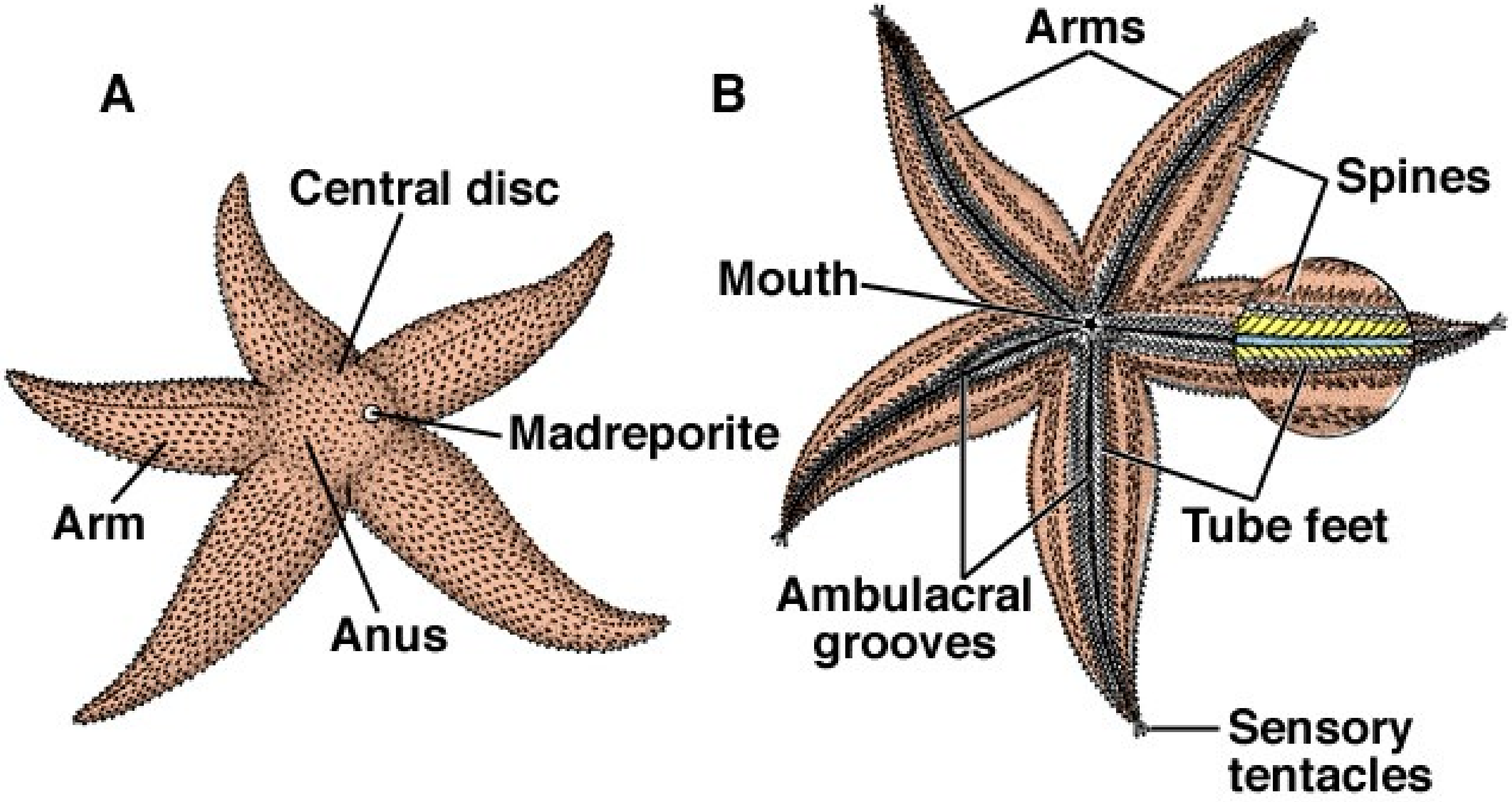
External anatomy of asteroid



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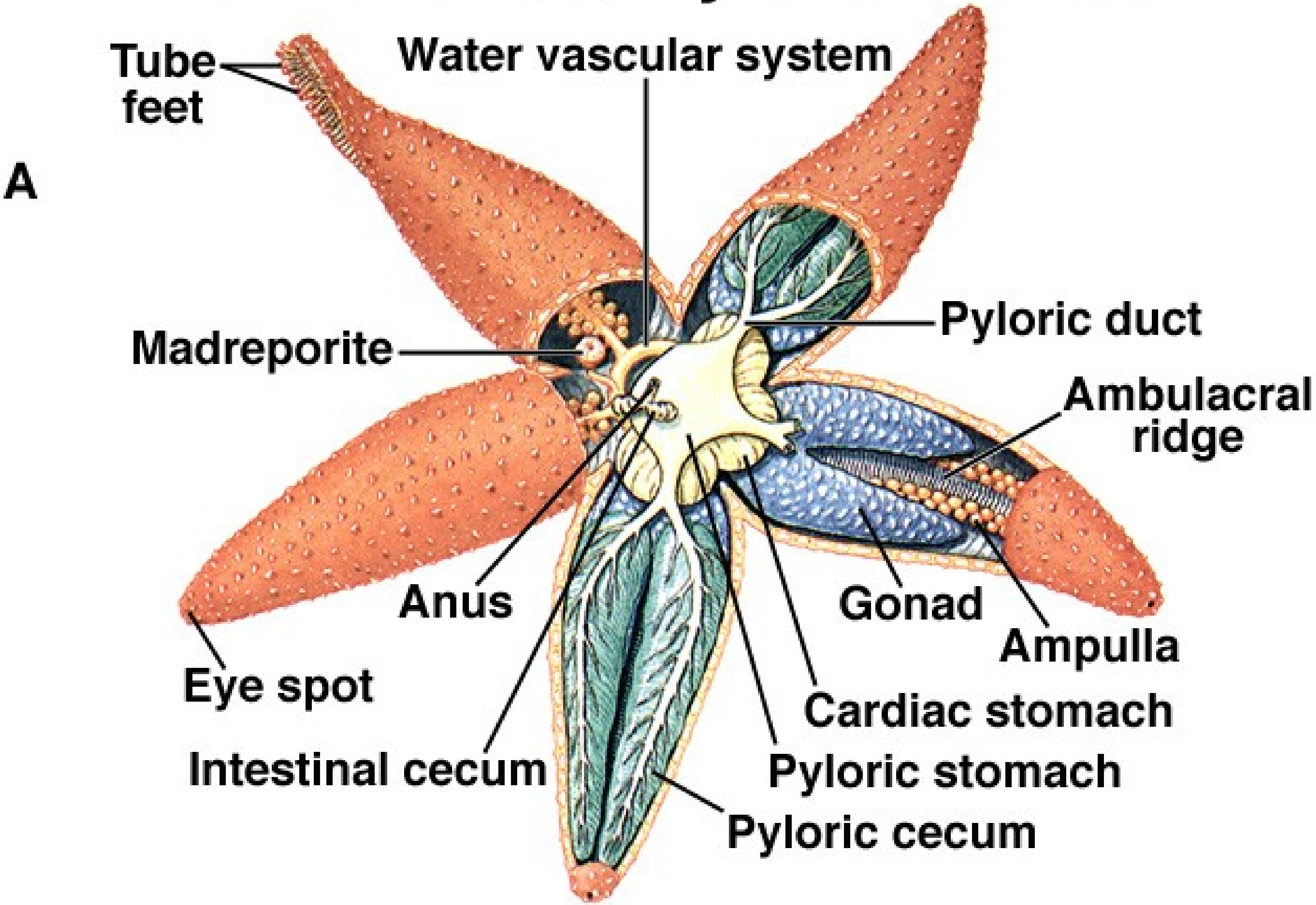
Internal anatomy of a sea star



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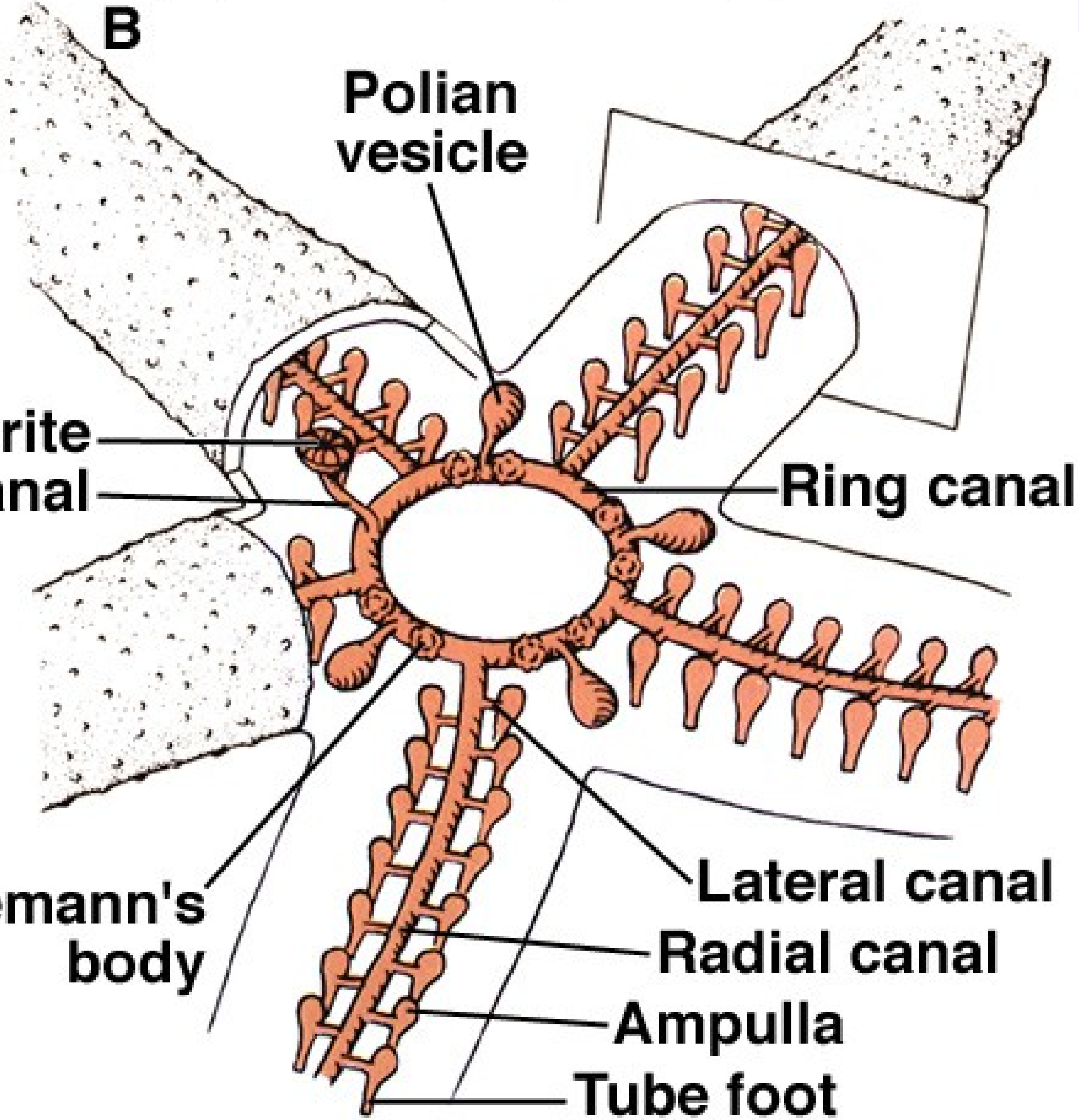
Water vascular system of a sea star



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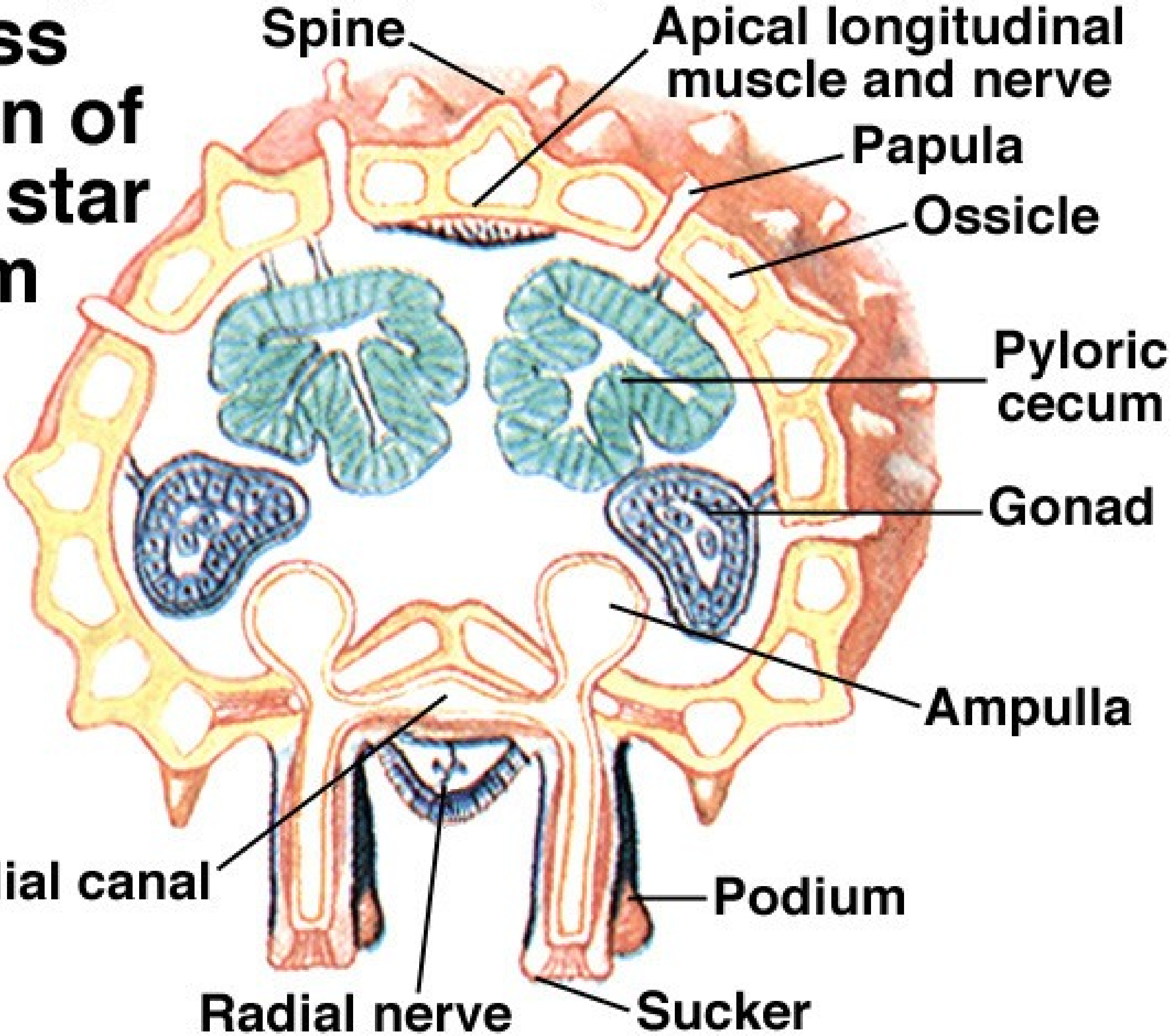
Cross section of a sea star arm



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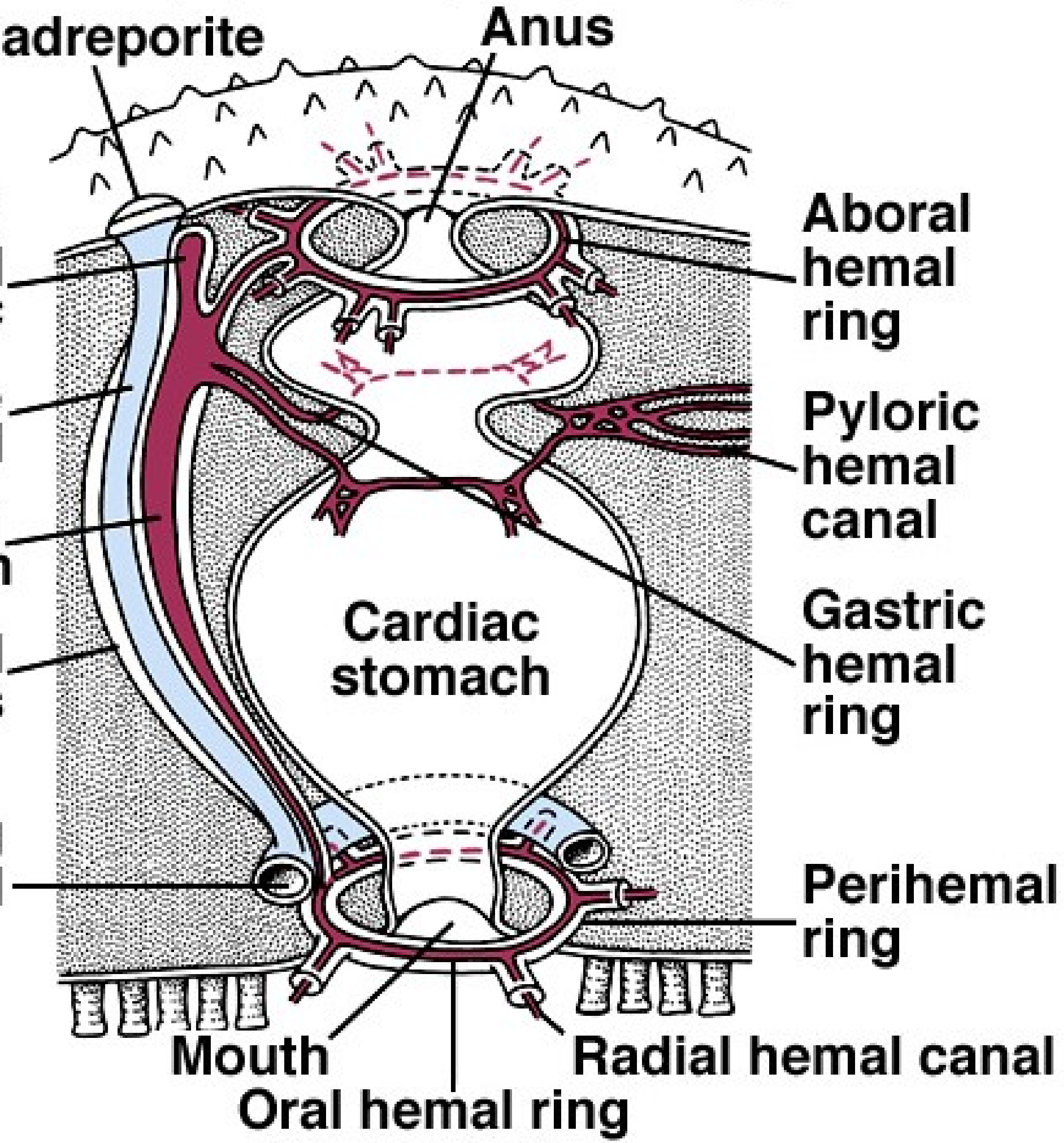
Hemal system of asteroids



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Pacific sea star

Tube fe
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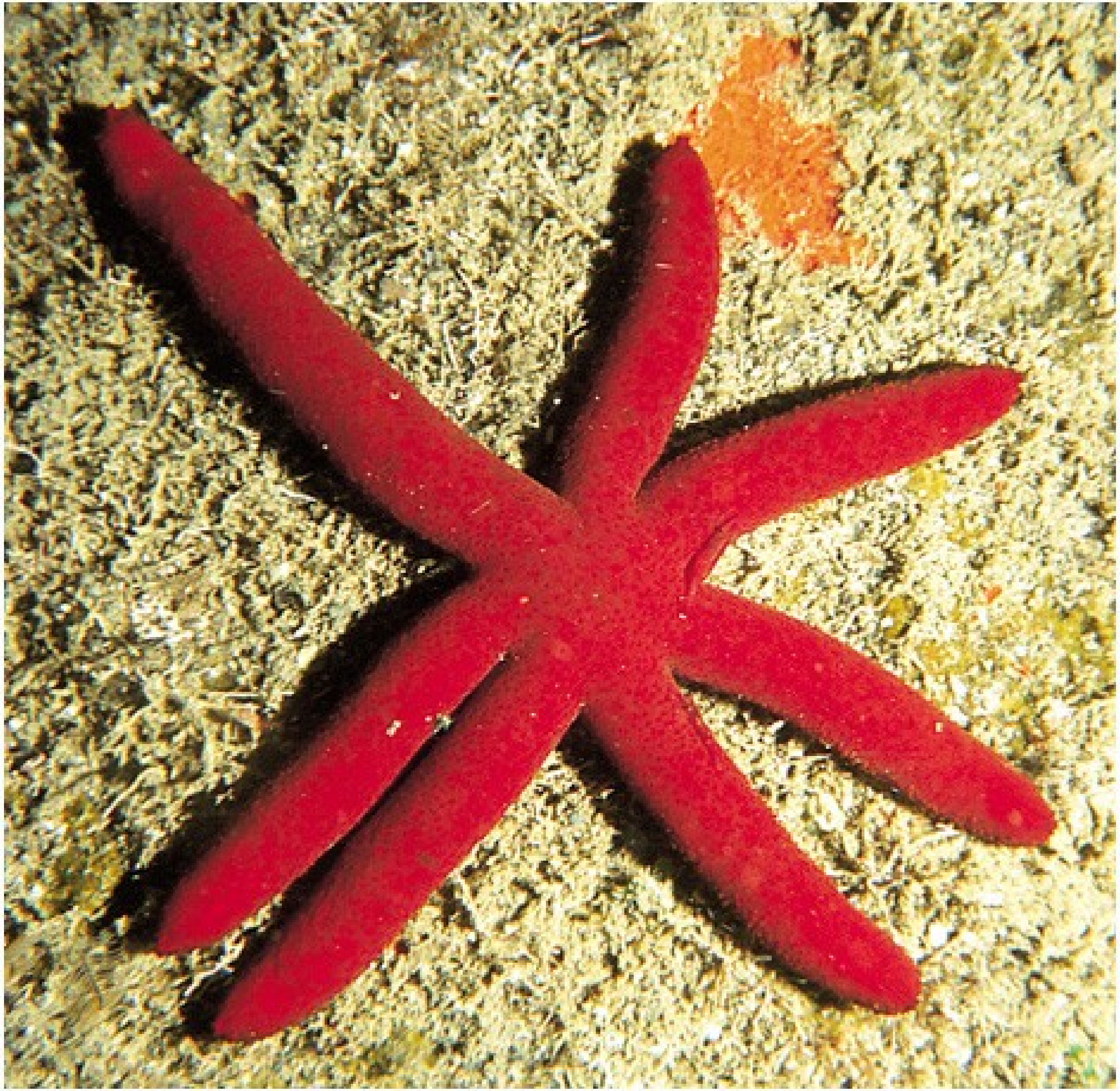

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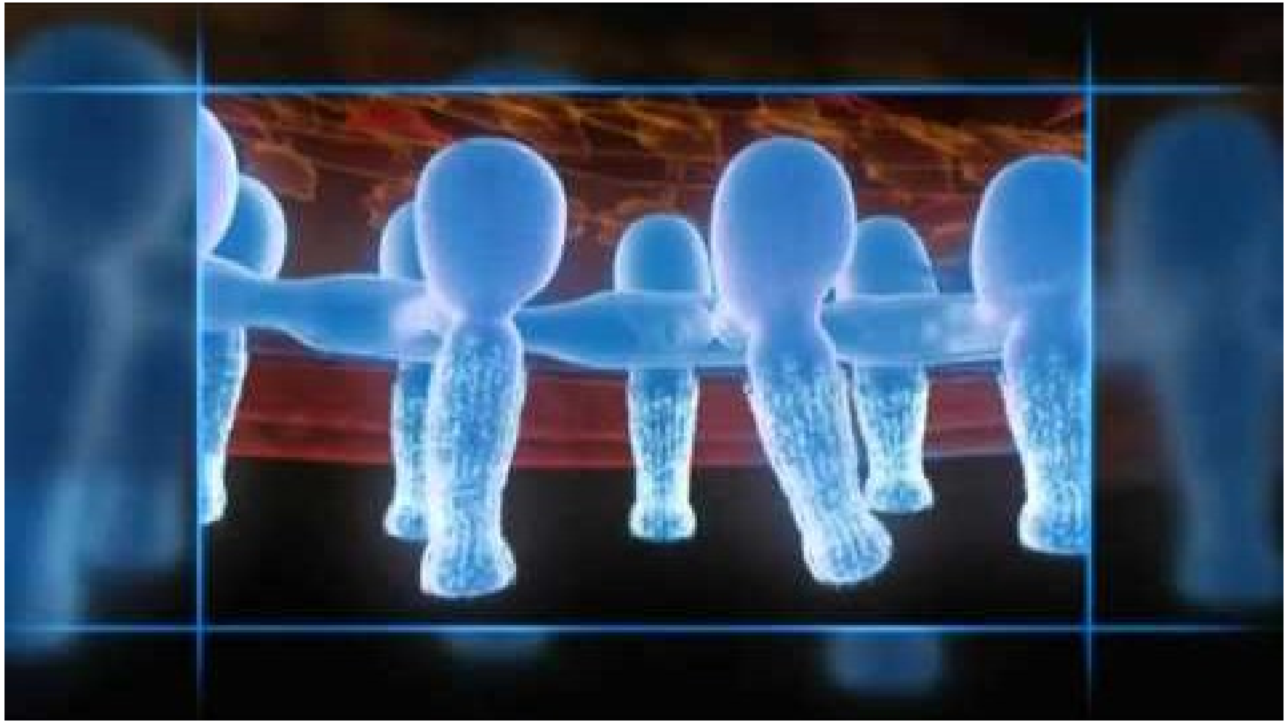
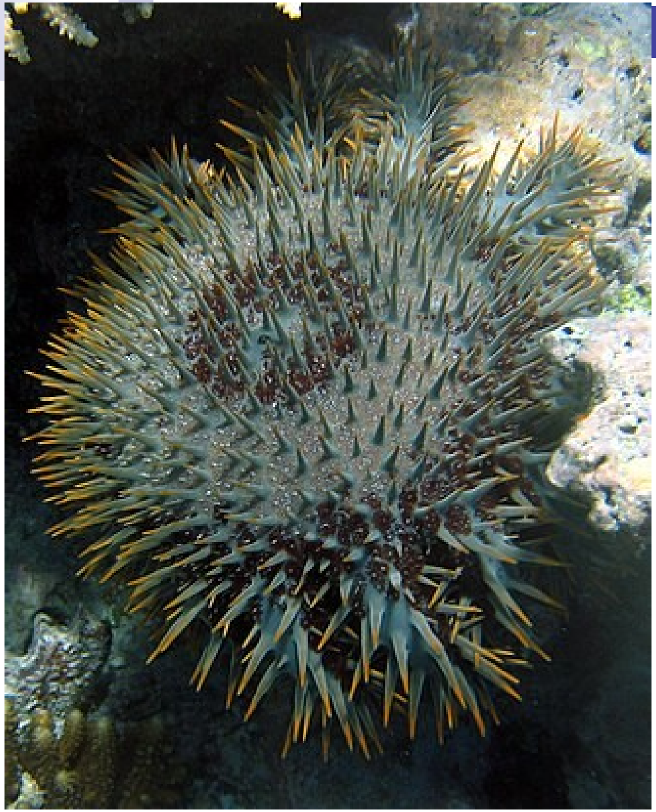
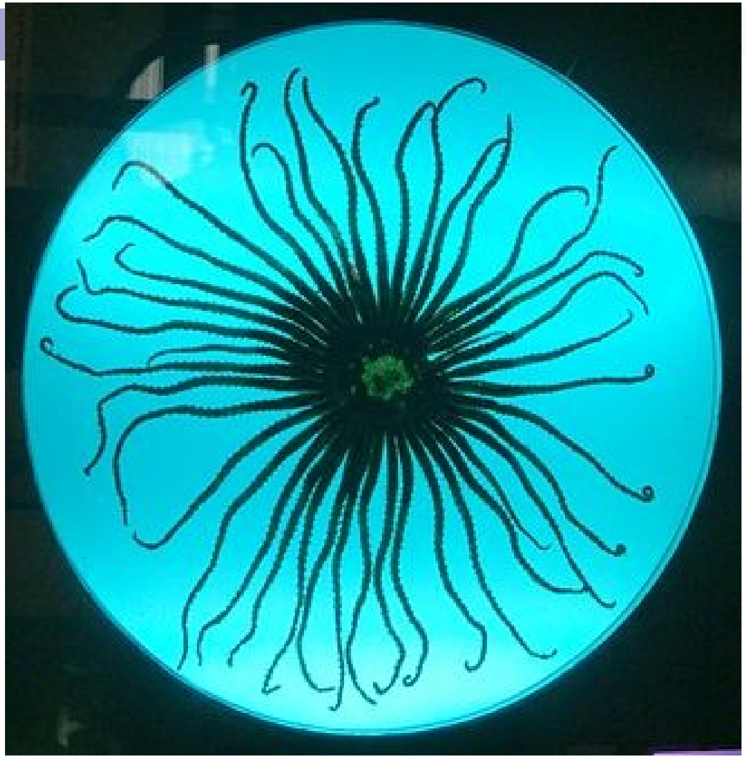




Crown of
Thorns Sea Star

Northern Pacific
Sea Star



Labidiaster sp.

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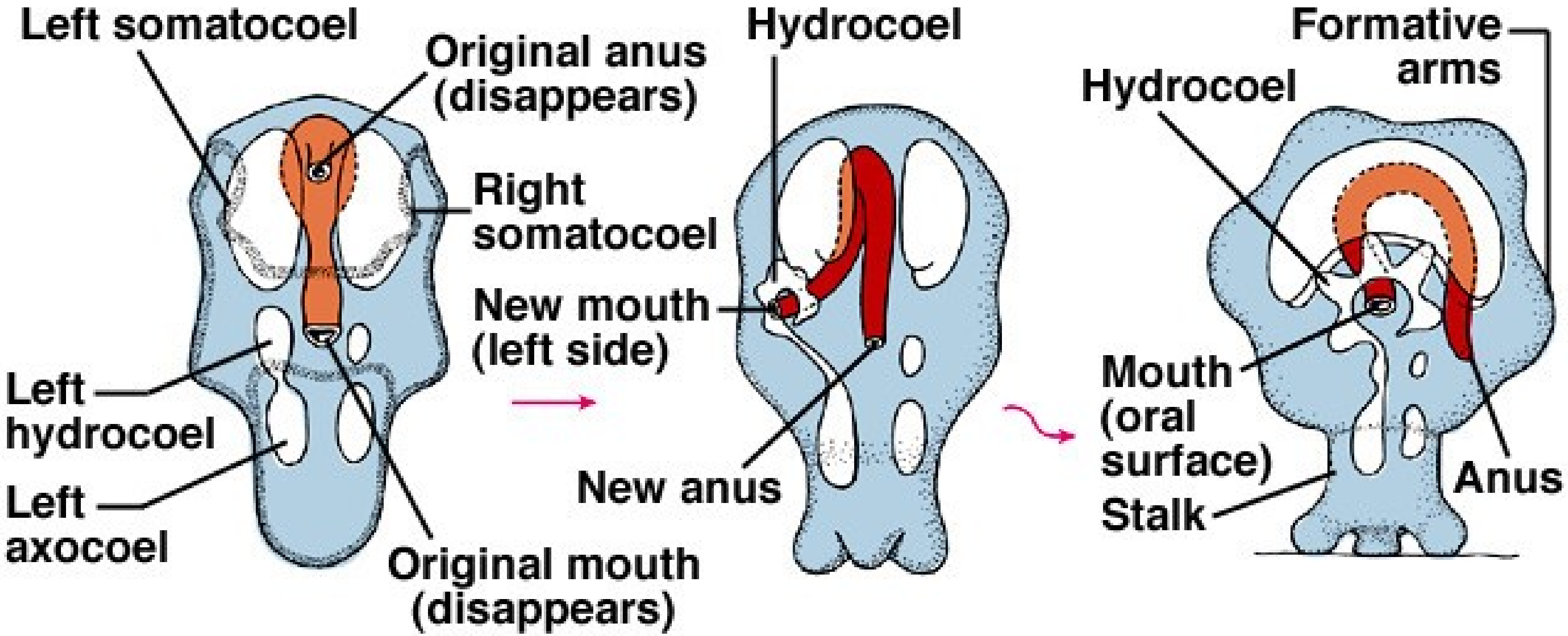
Asteroid metamorphosis



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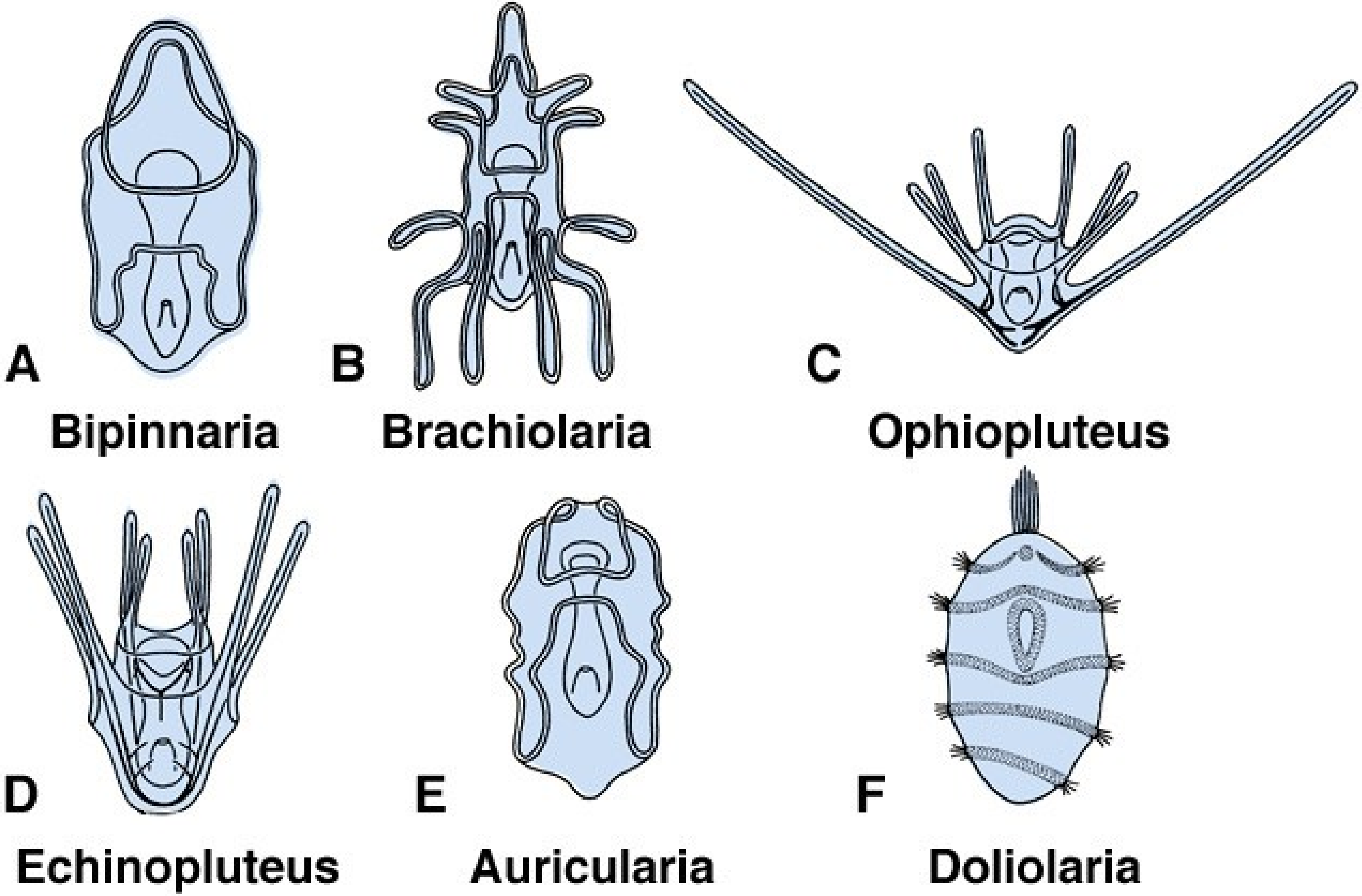
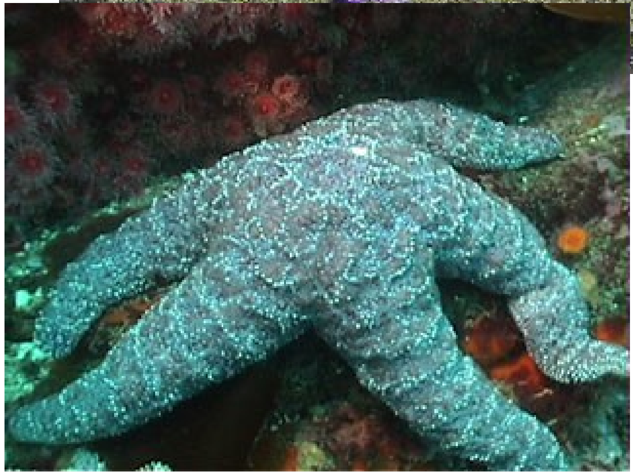
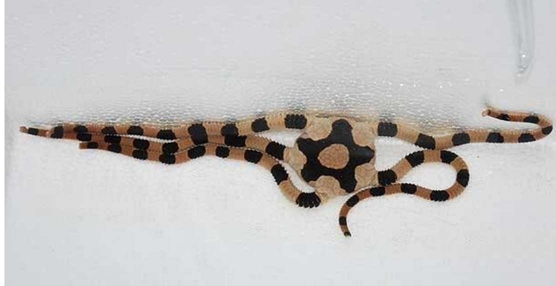
Larvae of echinoderms



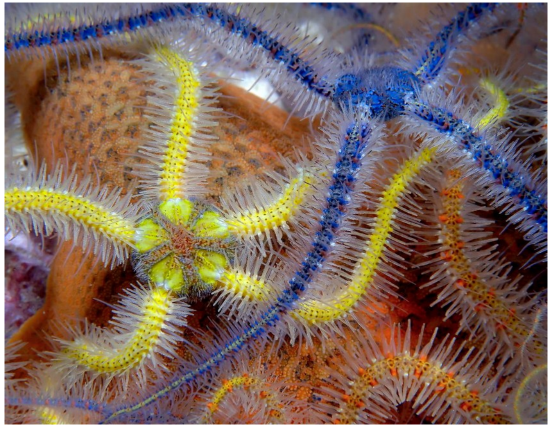


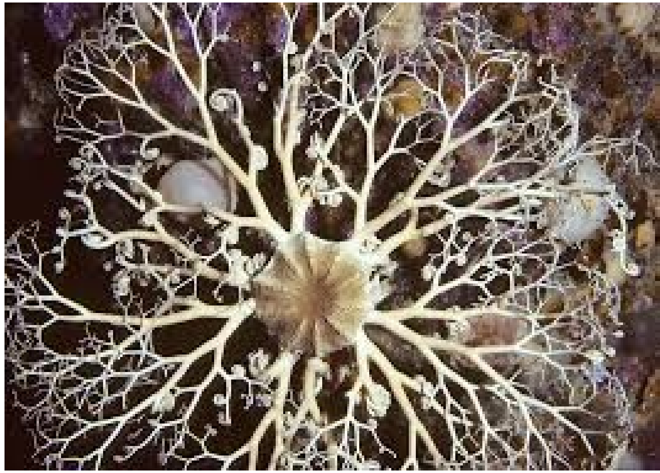
The Pacific Coast seastar, *Pisaster ochraeus* – a keystone species currently suffering from a wasting disease



Brittle, basket and serpent stars: Characteristics

- **Arms sharply demarcated from central disk**
- **Close ambulacral grooves, covered with ossicles**
- **Pedicellariae absent**
- **Tube feet without suckers and NOT used for locomotion**





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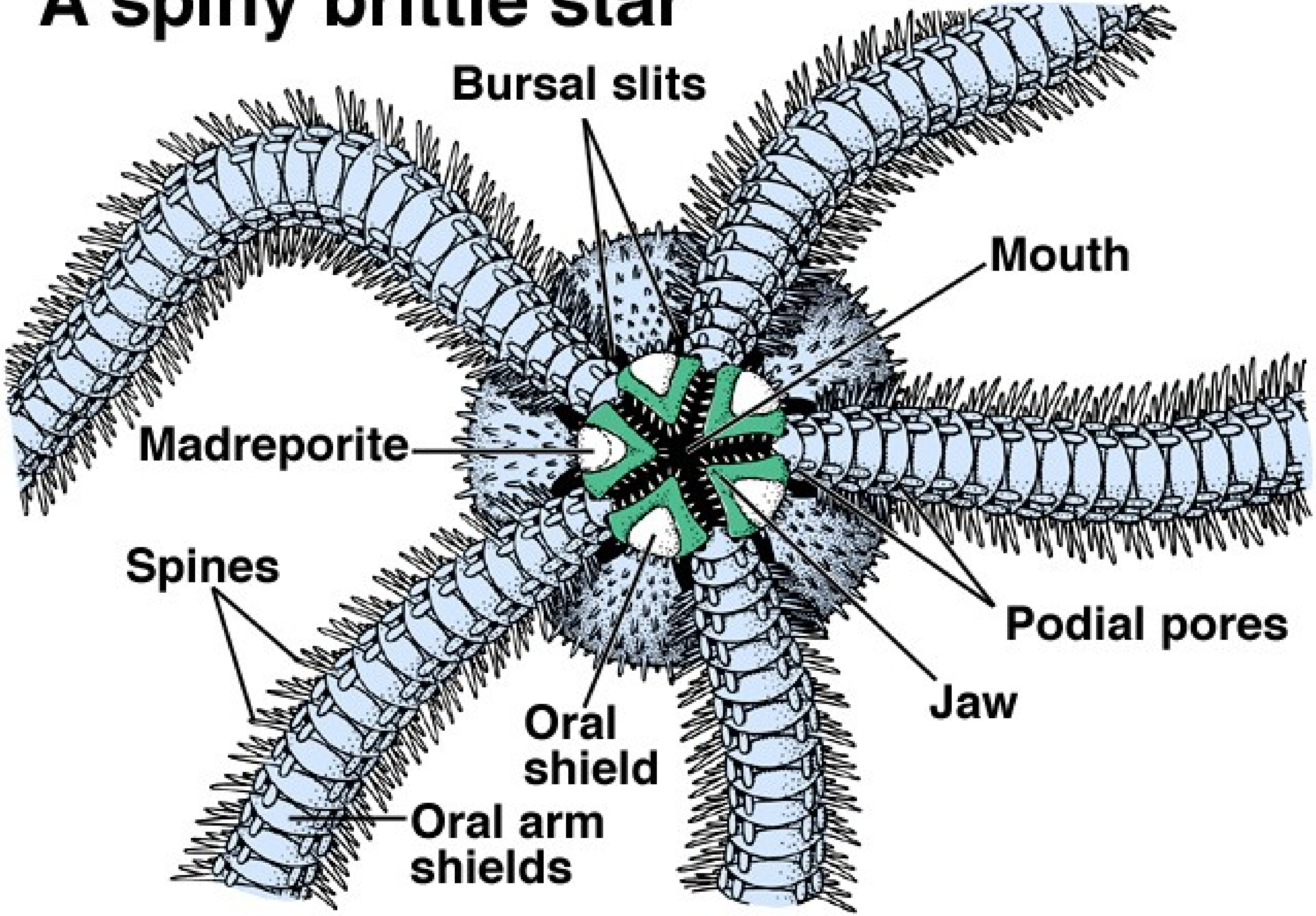
A spiny brittle star



Sea Urchins and Sand Dollars: Characteristics

- Globular or disk-shaped, no arms
- Close fitting TEST, with moveable spines
- Tube feet with suckers
- Pedicellariae present

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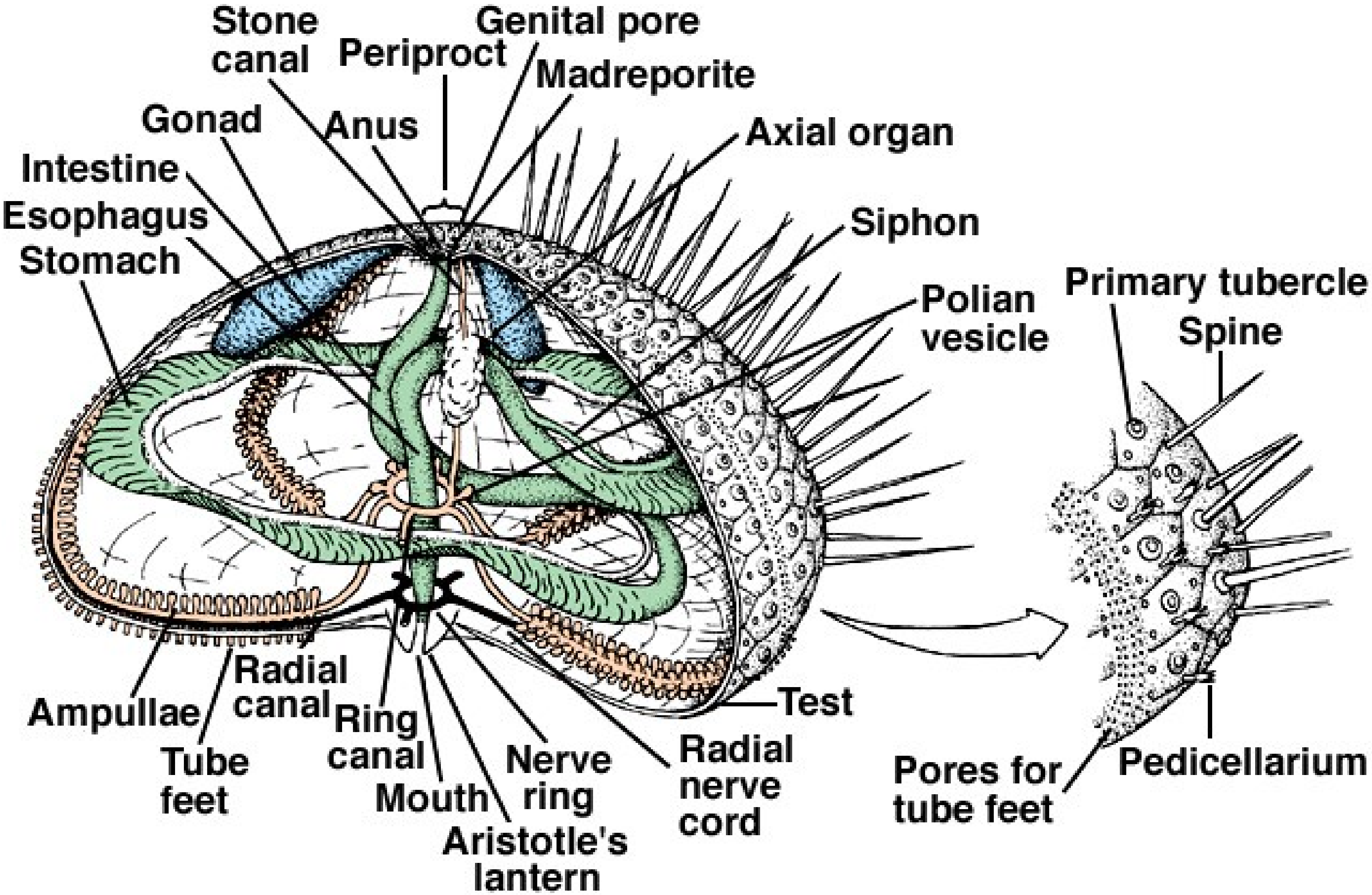
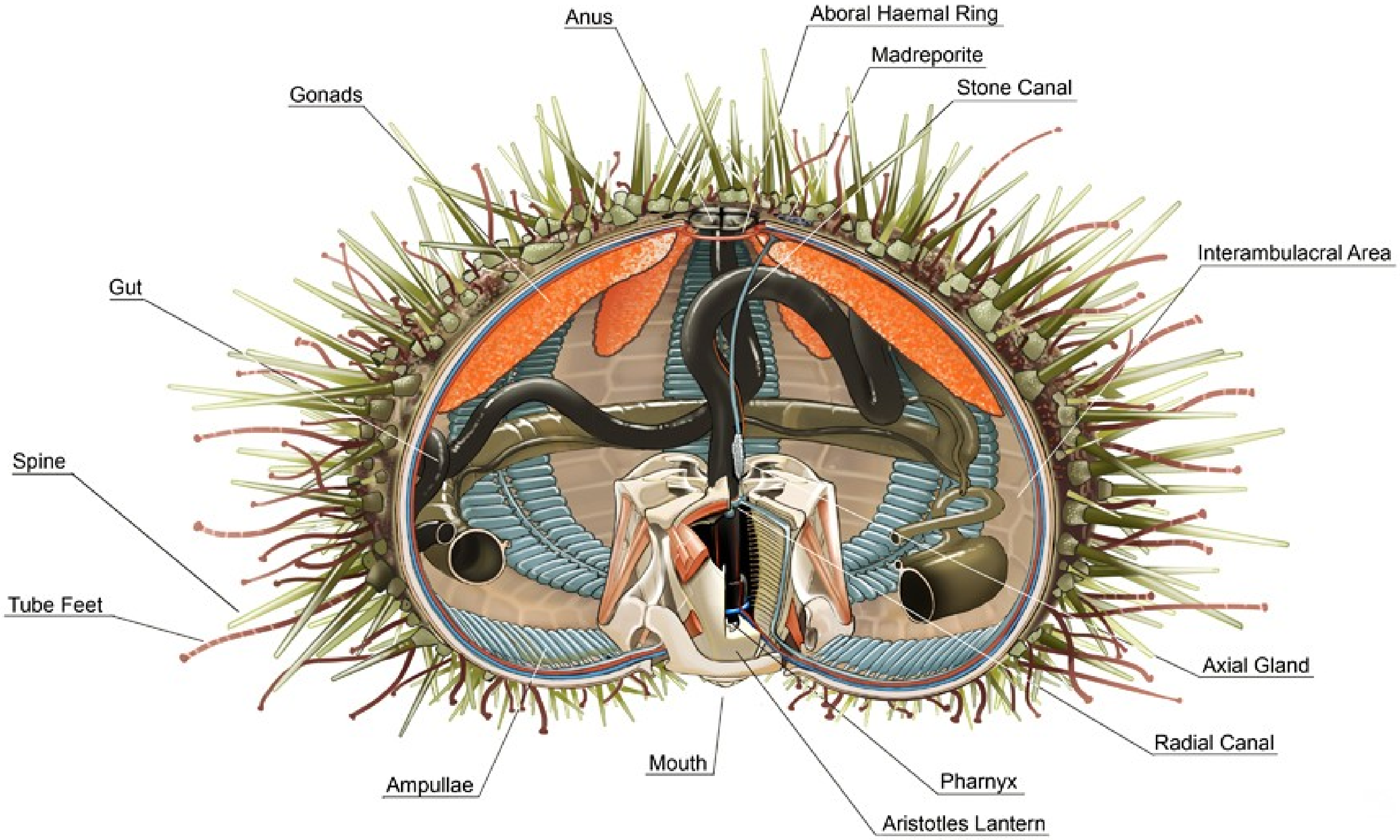
Internal structure of sea urchin



Sea urchin



Strongylocentrotus droebachiensis www.alexries.com

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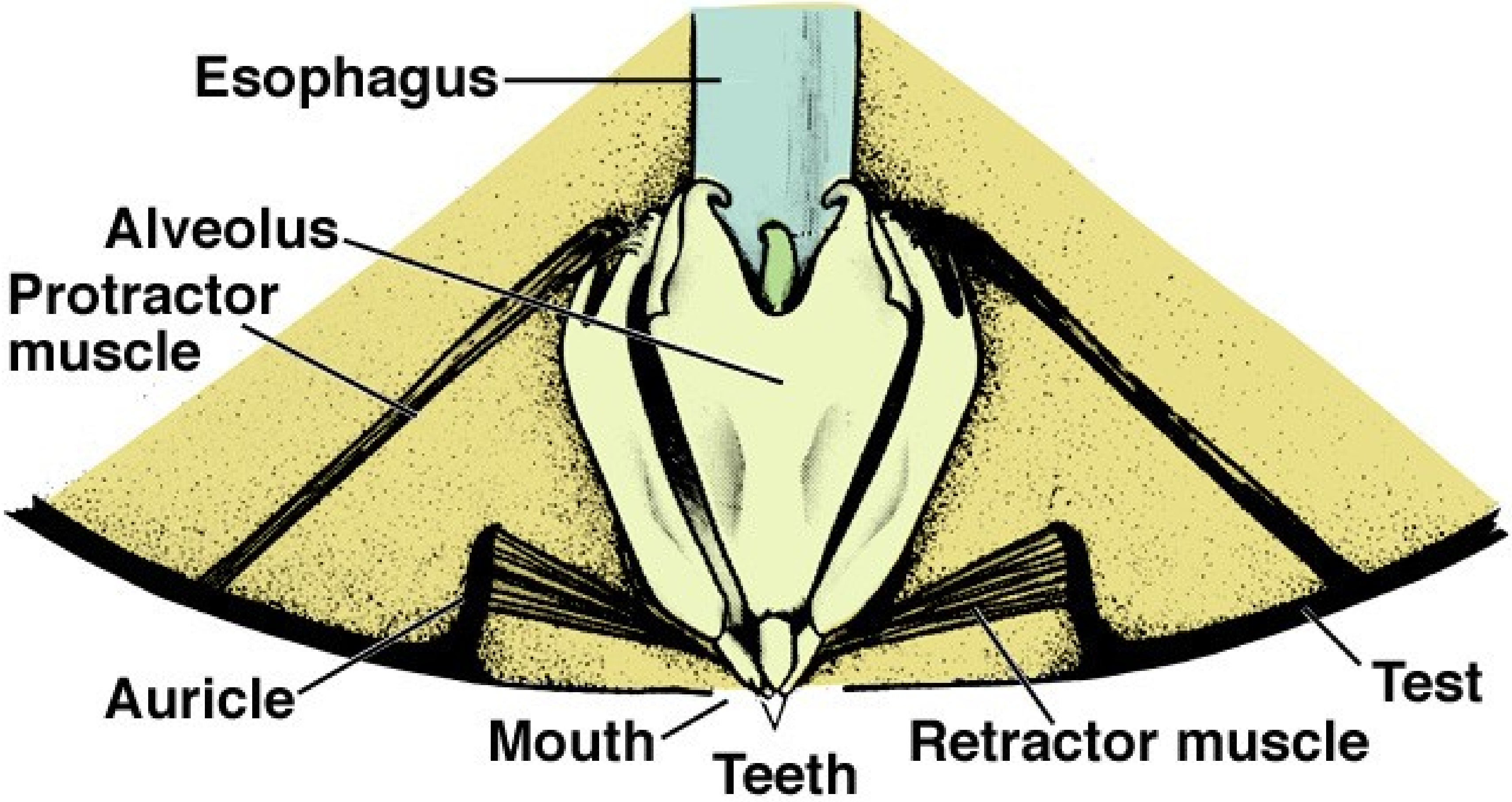
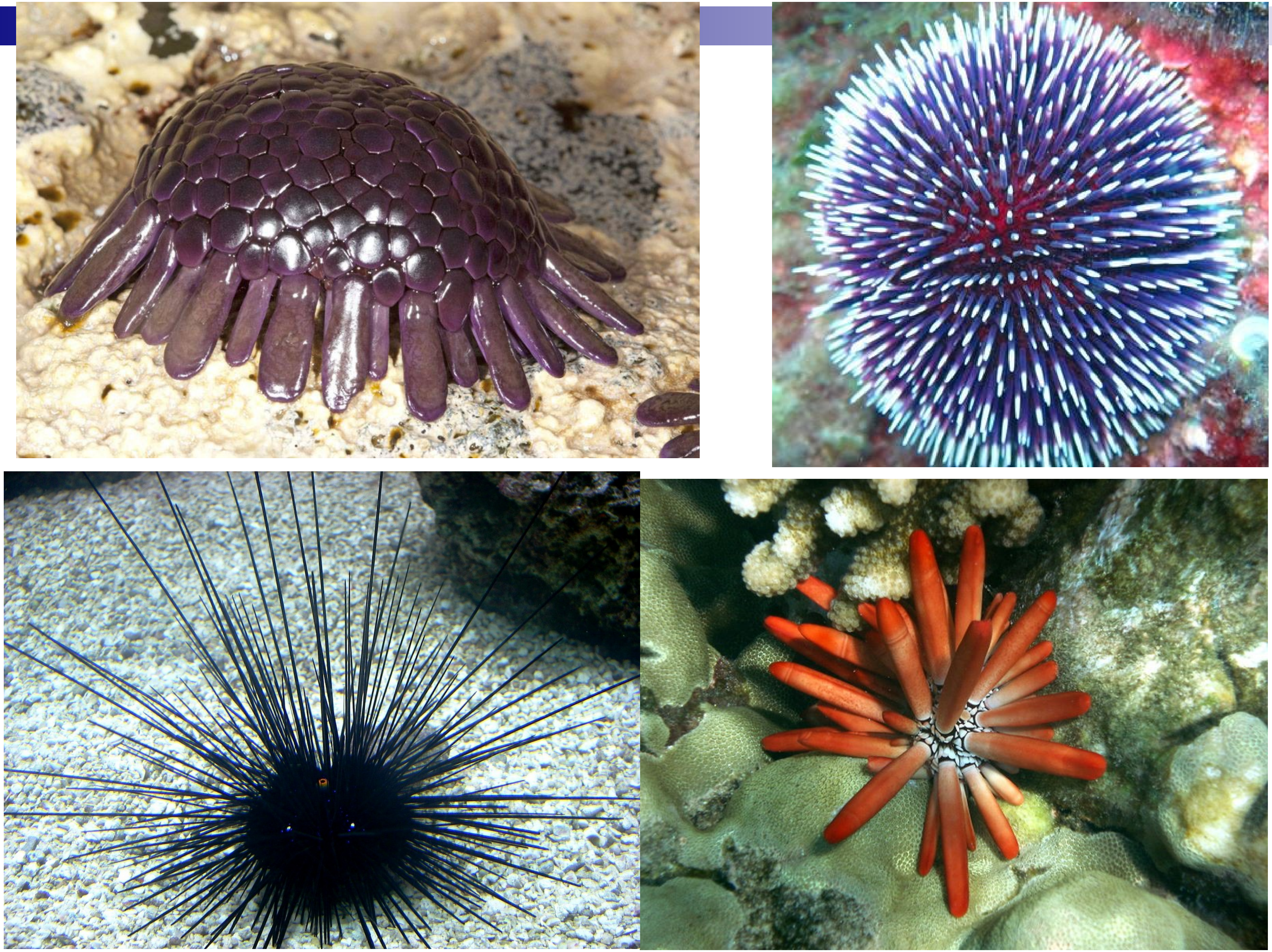
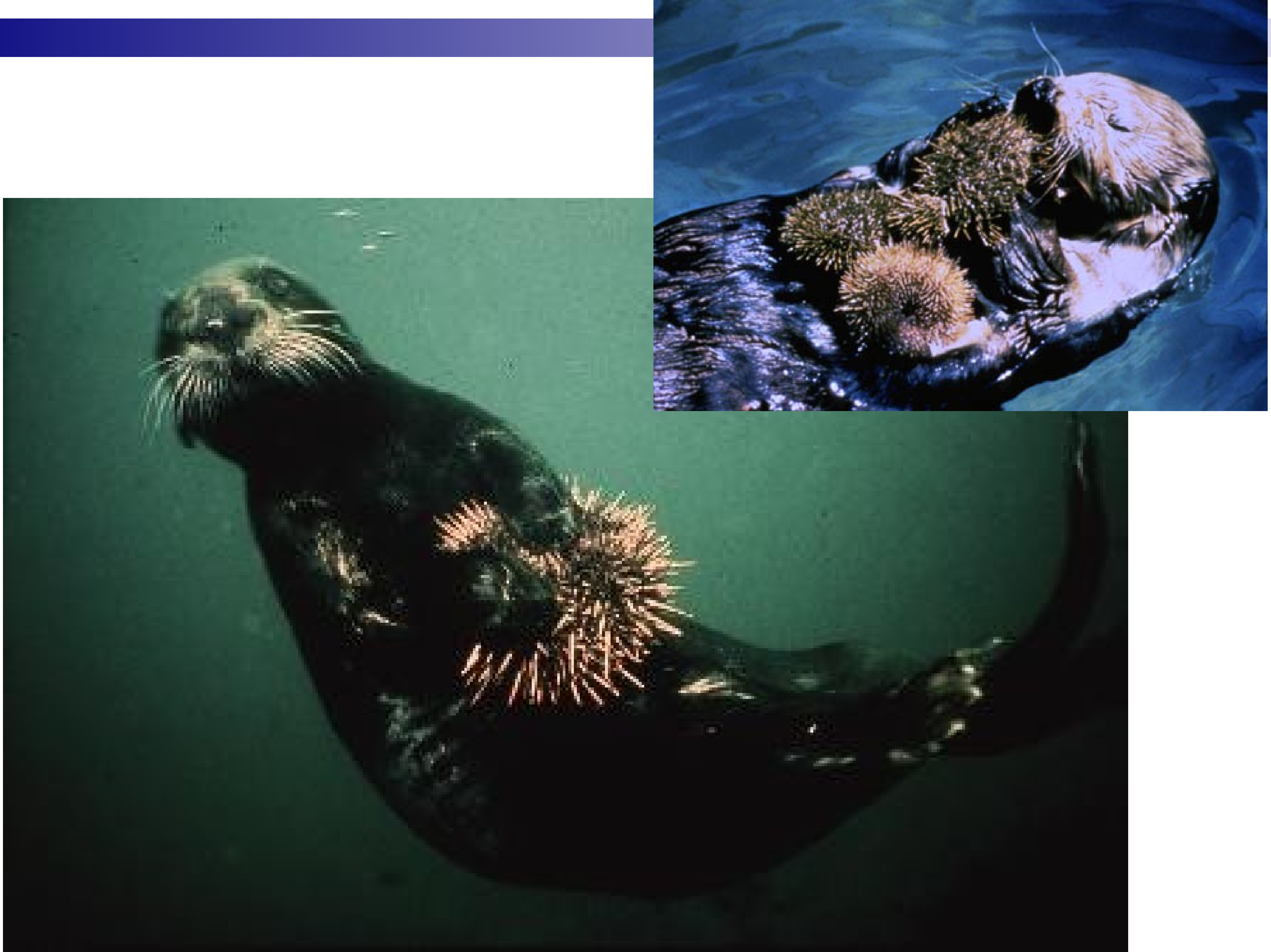
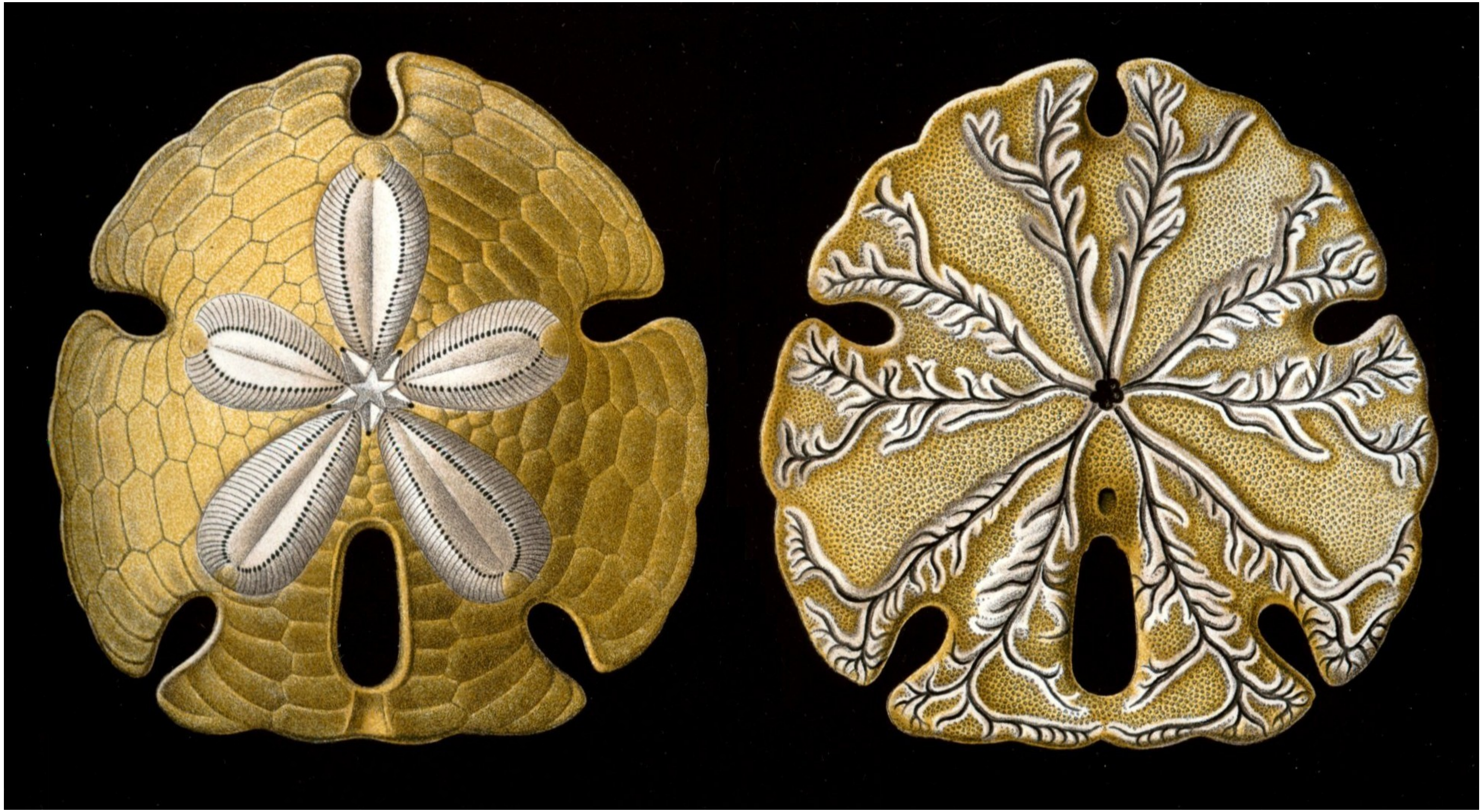
Aristotle's lantern







Sand dollar



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CLASS HOLOTHUROIDEA

Sea Cucumbers:

Characteristics

- **Cucumber-shaped, spines absent**
- **Ossicles embedded in muscular body wall**
- **Circumoral tentacles**
- **Pedicellariae absent**

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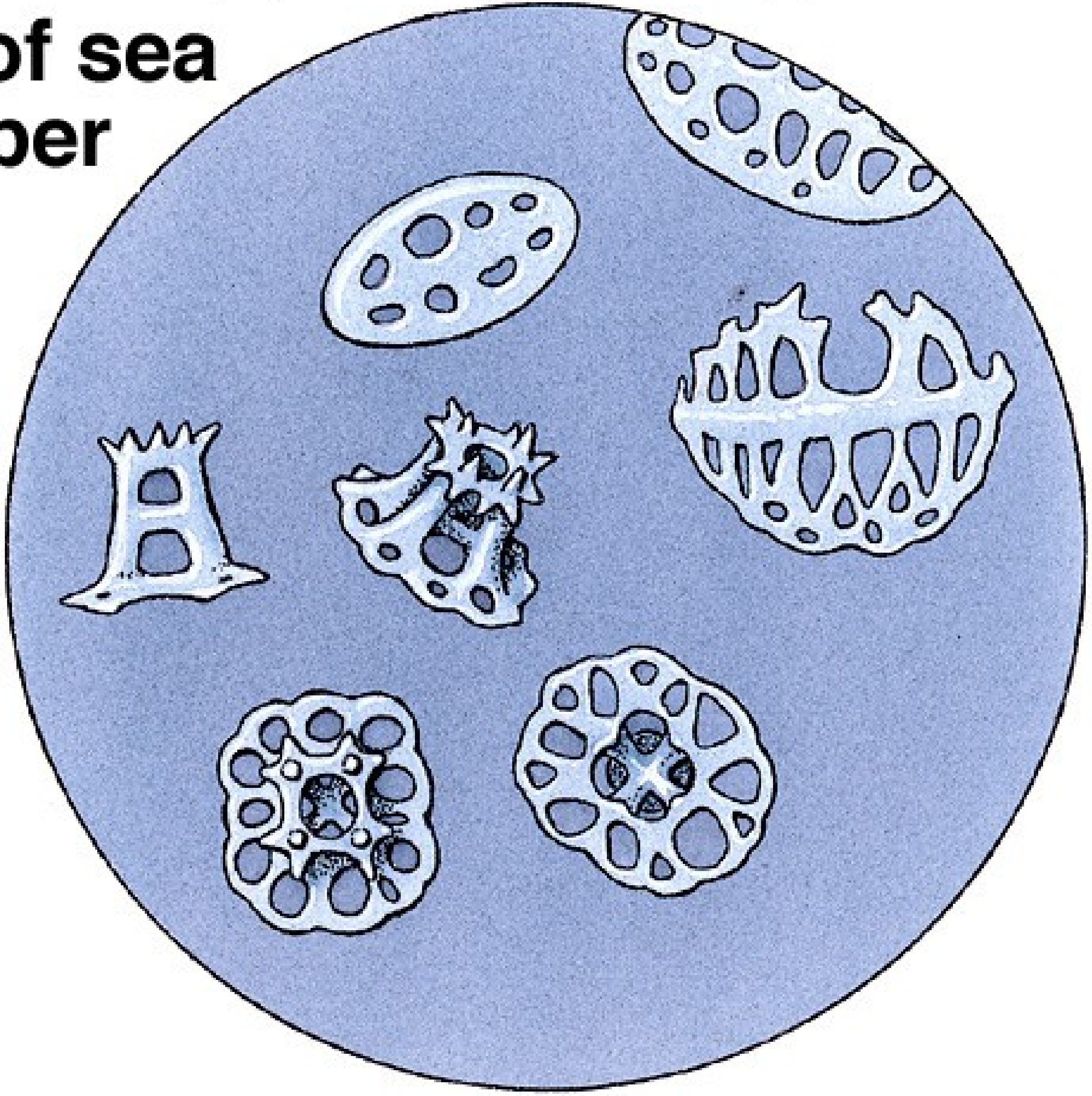
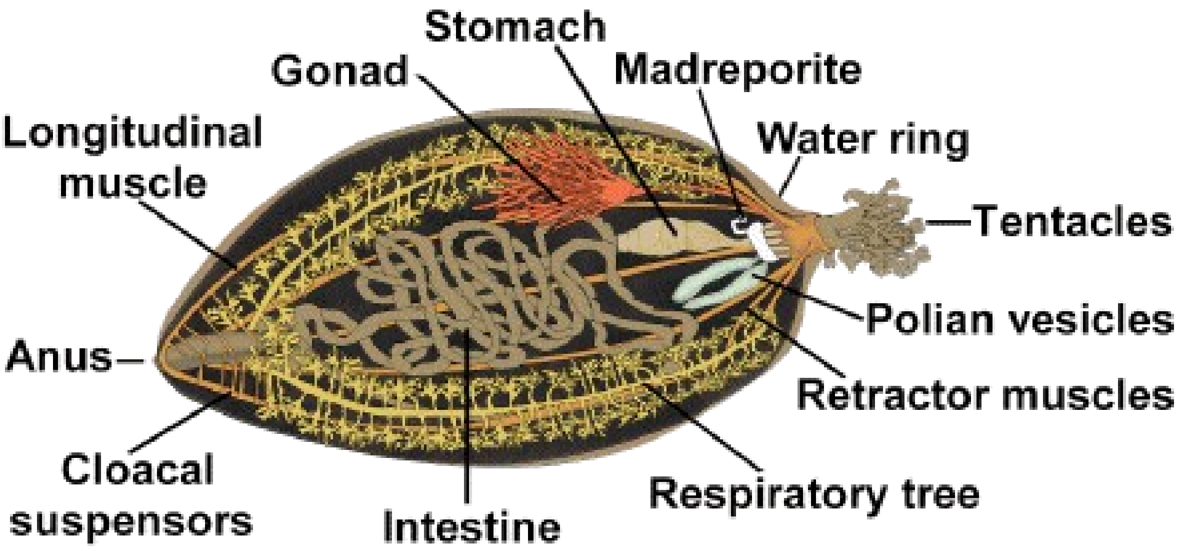
Ossicles of sea cucumber



Sea cucumber (CLASS HOLOTHUROIDEA)



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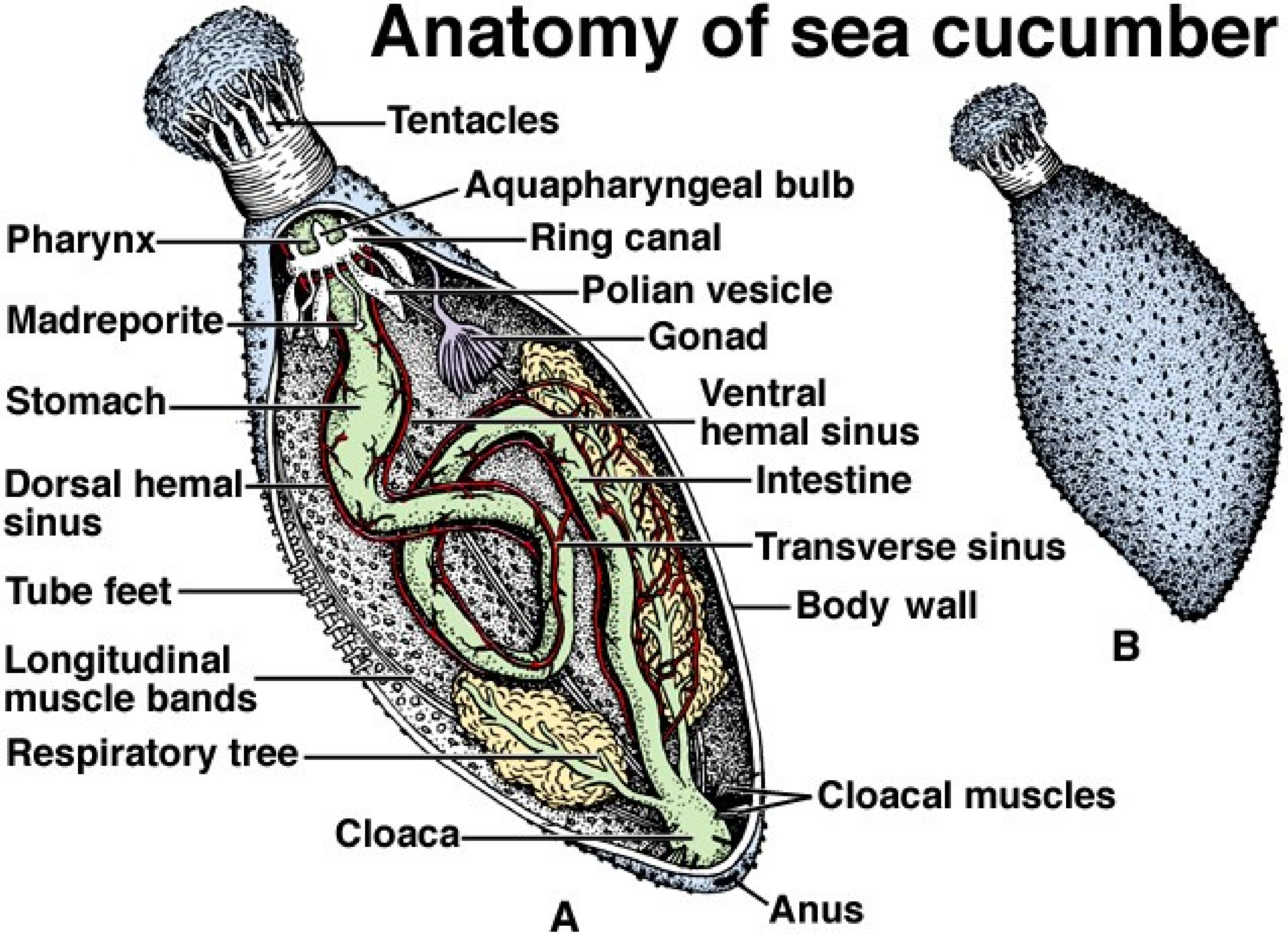
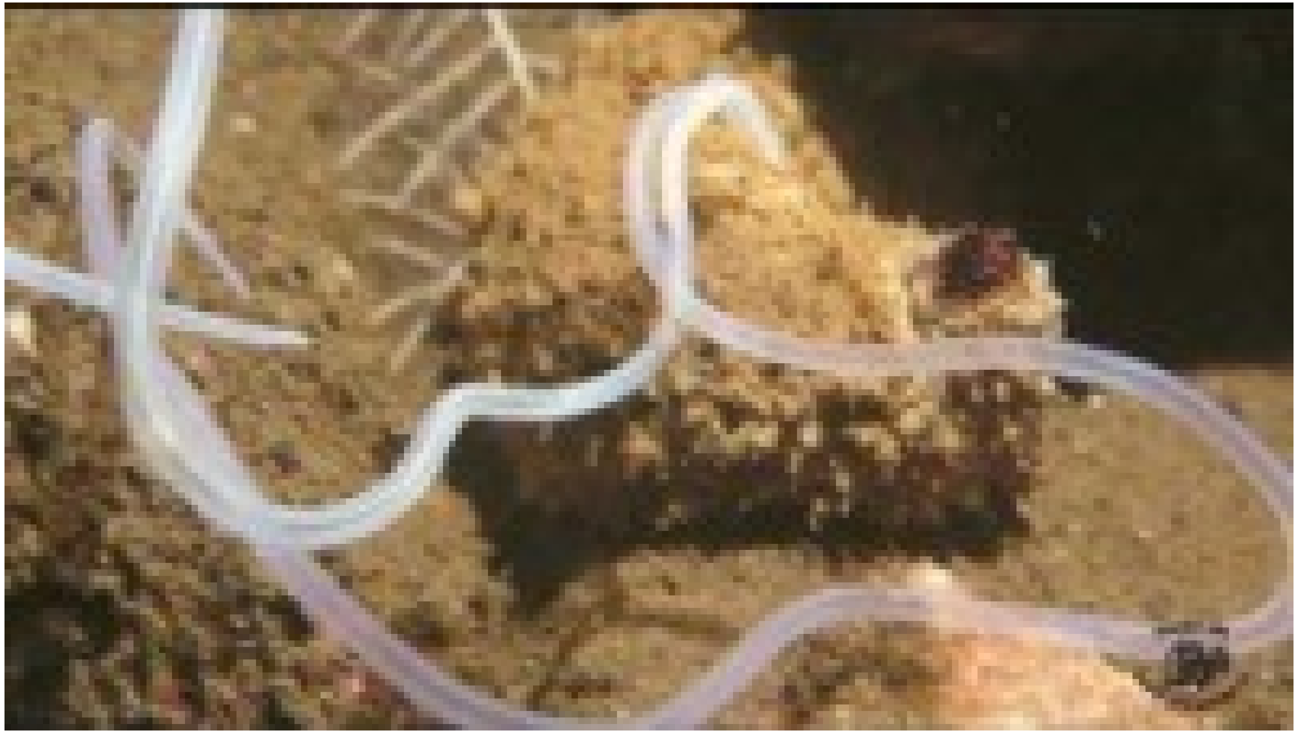
Anatomy of sea cucumber



Cuverian tubule defense



Braised sea cucumber with tea leaves

Pearlfish and sea cucumber

Crinoids, sea lilies and feather stars: Characteristics

- **5 arms branching at base**
- **Ciliated ambulacral grooves on oral surface, with tentacle- like tube feet for food gathering**
- **On an aboral stalk**
- **No spines, madreporite or pedicellariae**

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Living crinoid

Larry S. Roberts

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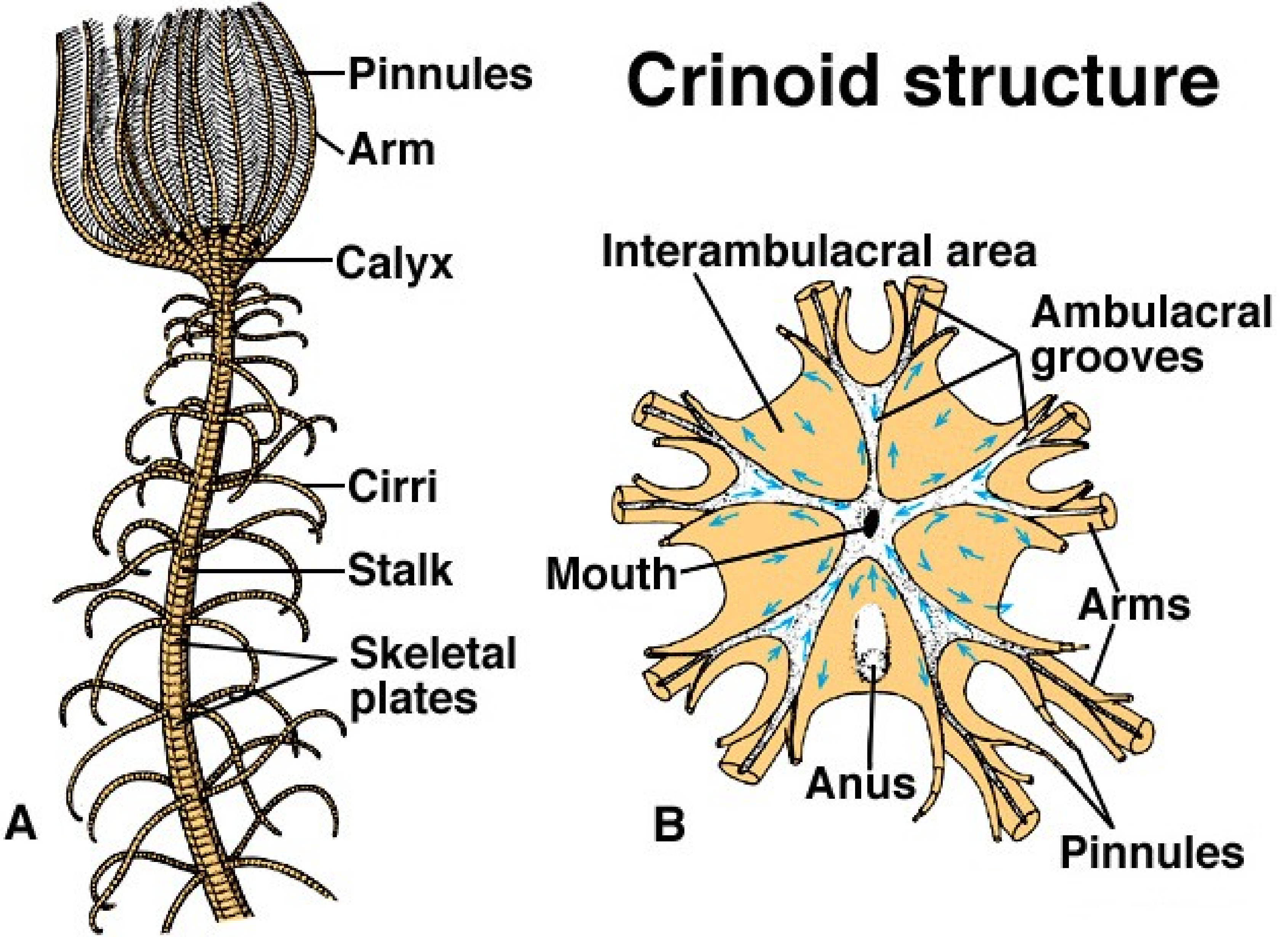
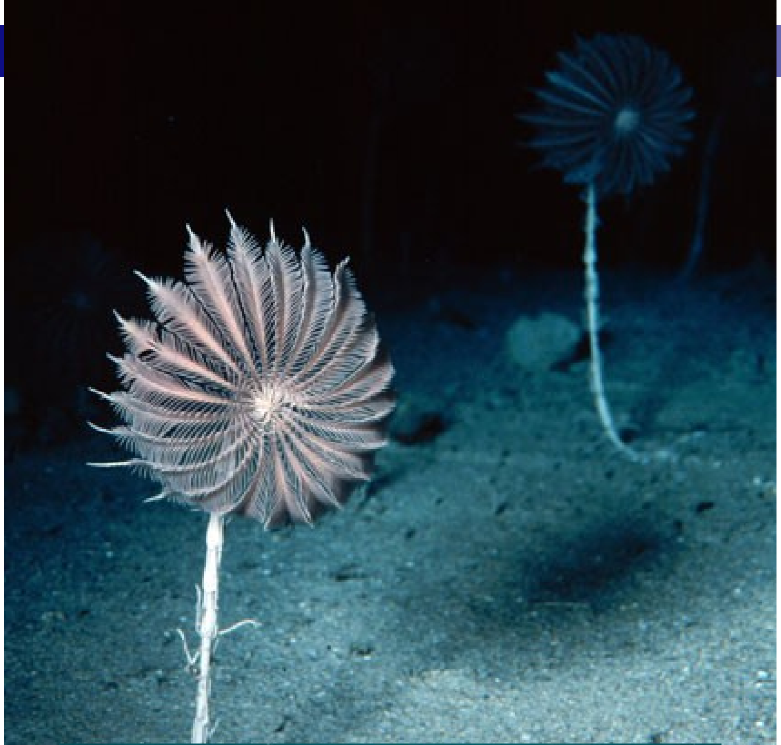
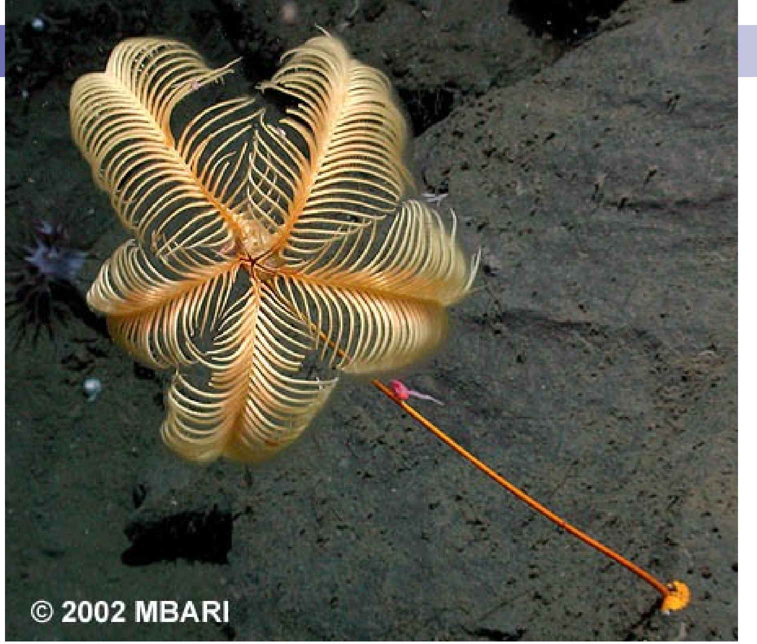
Crinoid structure







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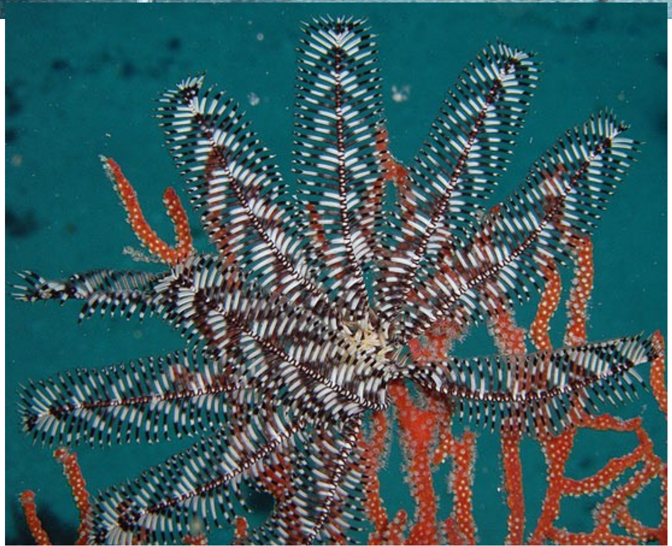
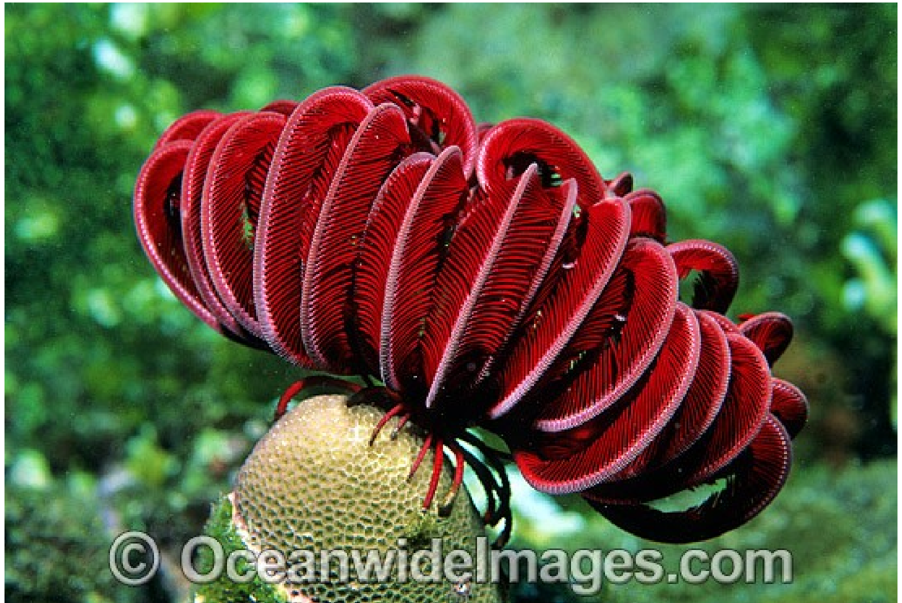
Sea
lily



Feather
star



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Characteristics

- Calcareous endoskeleton composed of separate plates or OSSICLES
- Pentaradial symmetry (derived from bilaterally symmetrical larval forms)
- Deuterostome
- Water vascular system ("tube feet")
- Complete gut (but secondarily lost in some species)
- Decentralized nervous system
- Entirely marine
- Ciliated epidermis and PEDICELLARIA (not in all)
- NO excretory system
- Autotomy – Can intentionally detach body part that will later regenerate
- Dioecious

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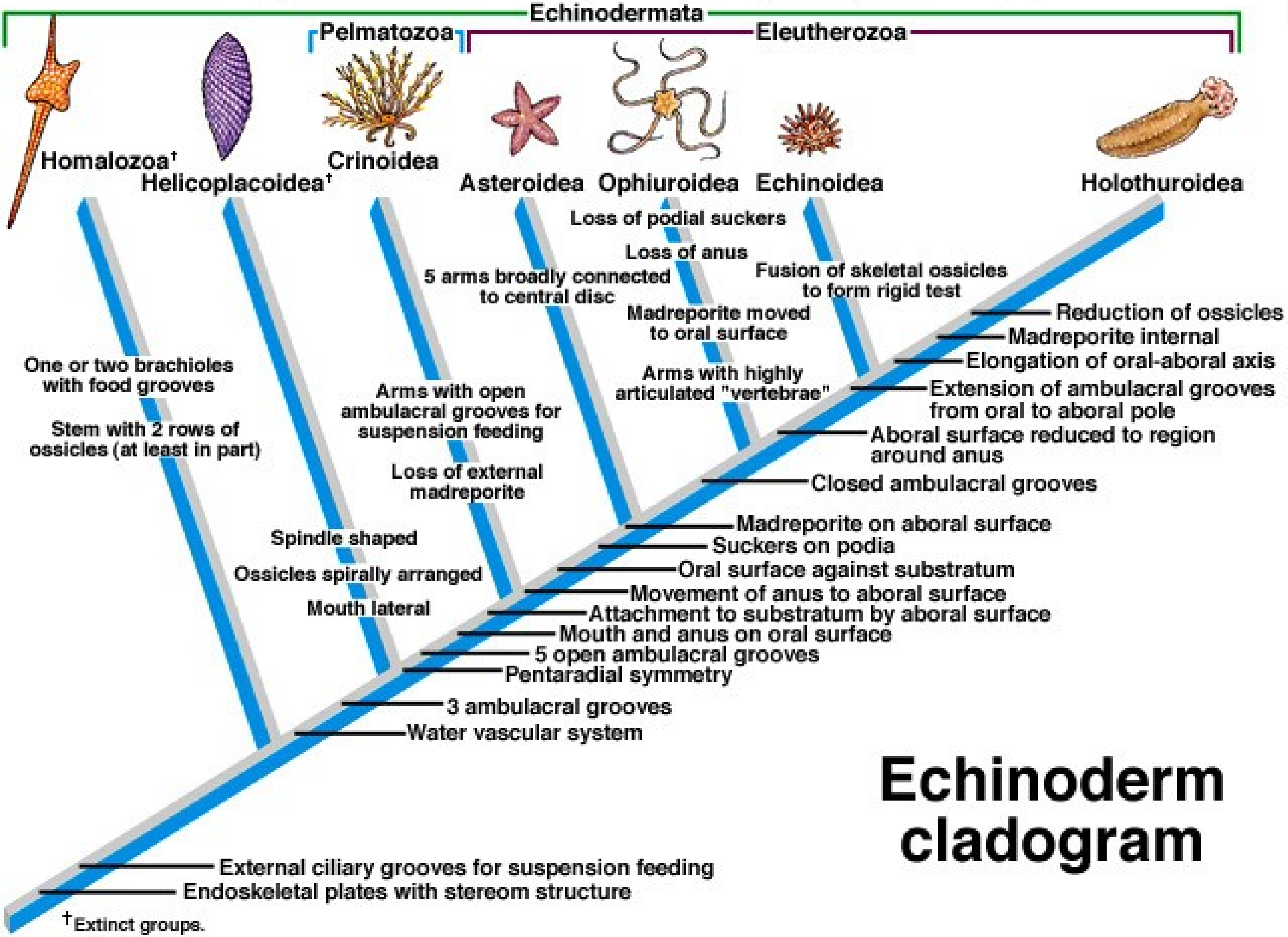
Echinoderm cladogram



Echinodermata

Pelmatozoa

Eleutherozoa

Homalozoa†

Helicoplacoidea†

Crinoidea

Asteroidea

Ophiuroidea

Echinoidea

Holothuroidea

One or two brachioles with food grooves

Stem with 2 rows of ossicles (at least in part)

Spindle shaped

Ossicles spirally arranged

Mouth lateral

Arms with open ambulacral grooves for suspension feeding

Loss of external madreporite

5 arms broadly connected to central disc

Loss of podial suckers

Loss of anus

Madreporite moved to oral surface

Arms with highly articulated "vertebrae"

Fusion of skeletal ossicles to form rigid test

Reduction of ossicles

Madreporite internal

Elongation of oral-aboral axis

Extension of ambulacral grooves from oral to aboral pole

Aboral surface reduced to region around anus

Closed ambulacral grooves

Madreporite on aboral surface

Suckers on podia

Oral surface against substratum

Movement of anus to aboral surface

Attachment to substratum by aboral surface

Mouth and anus on oral surface

5 open ambulacral grooves

Pentaradial symmetry

3 ambulacral grooves

Water vascular system

External ciliary grooves for suspension feeding

Endoskeletal plates with stereom structure

†Extinct groups.

EARLY CHORDATES

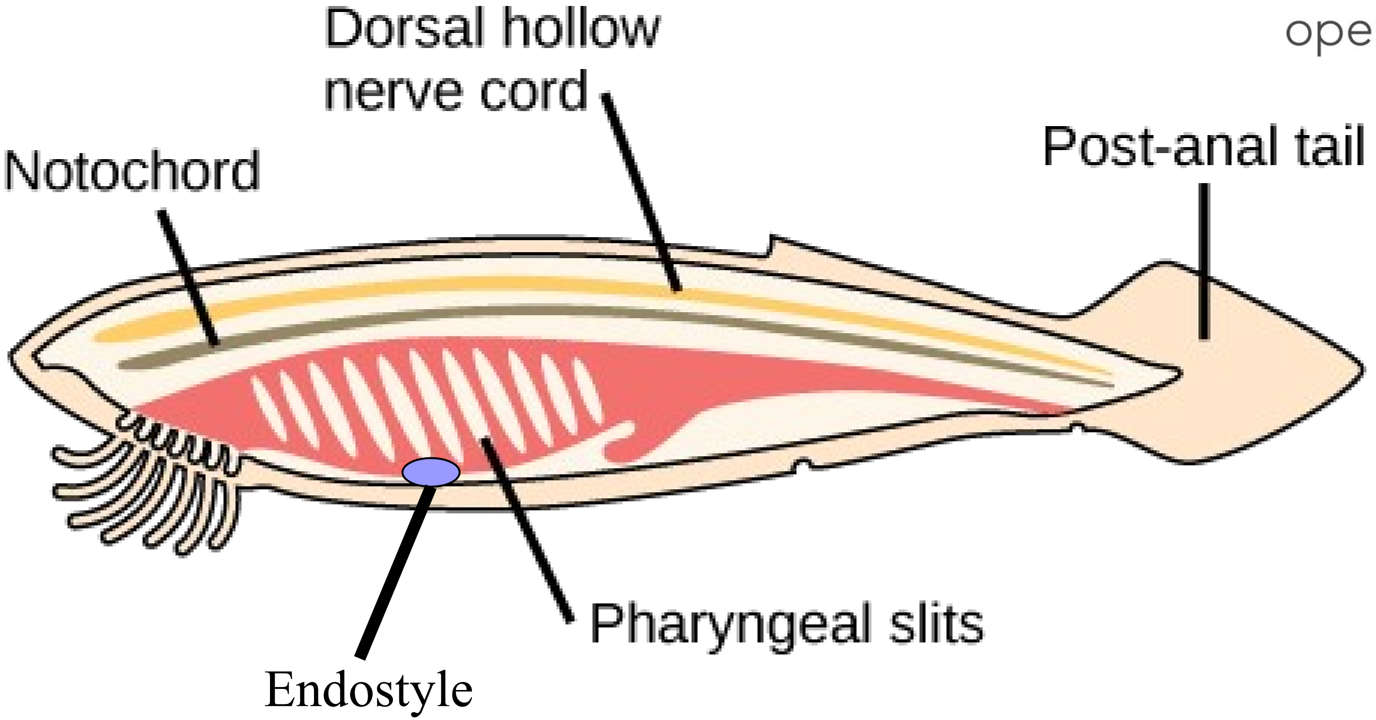
Phylum Chordata

- Key distinguishing innovations
1. **Notochord**
2. **Dorsal hollow nerve cord**
3. **Pharyngeal slits**
4. **Postanal tail**
5. **Endostyle**

PHYLUM CHORDATA – The Chordates

- Notochord present at some stage in development
- Single, dorsal, tubular nerve cord, anterior enlarged to form a BRAIN
- Pharyngeal pouches 🗳 GILL SLITS
- Postanal tail
- Endostyle
- Segmented muscles in unsegmented trunk
- Complete digestive tract
- Most members of the phylum (except the two subphyla below) have an ENDOSKELETON of BONE or CARTILAGE

Figure 29.3



- In chordates, five common features appear at some point during development: a notochord, a dorsal hollow nerve cord, pharyngeal slits, endostyle and a post-anal tail.

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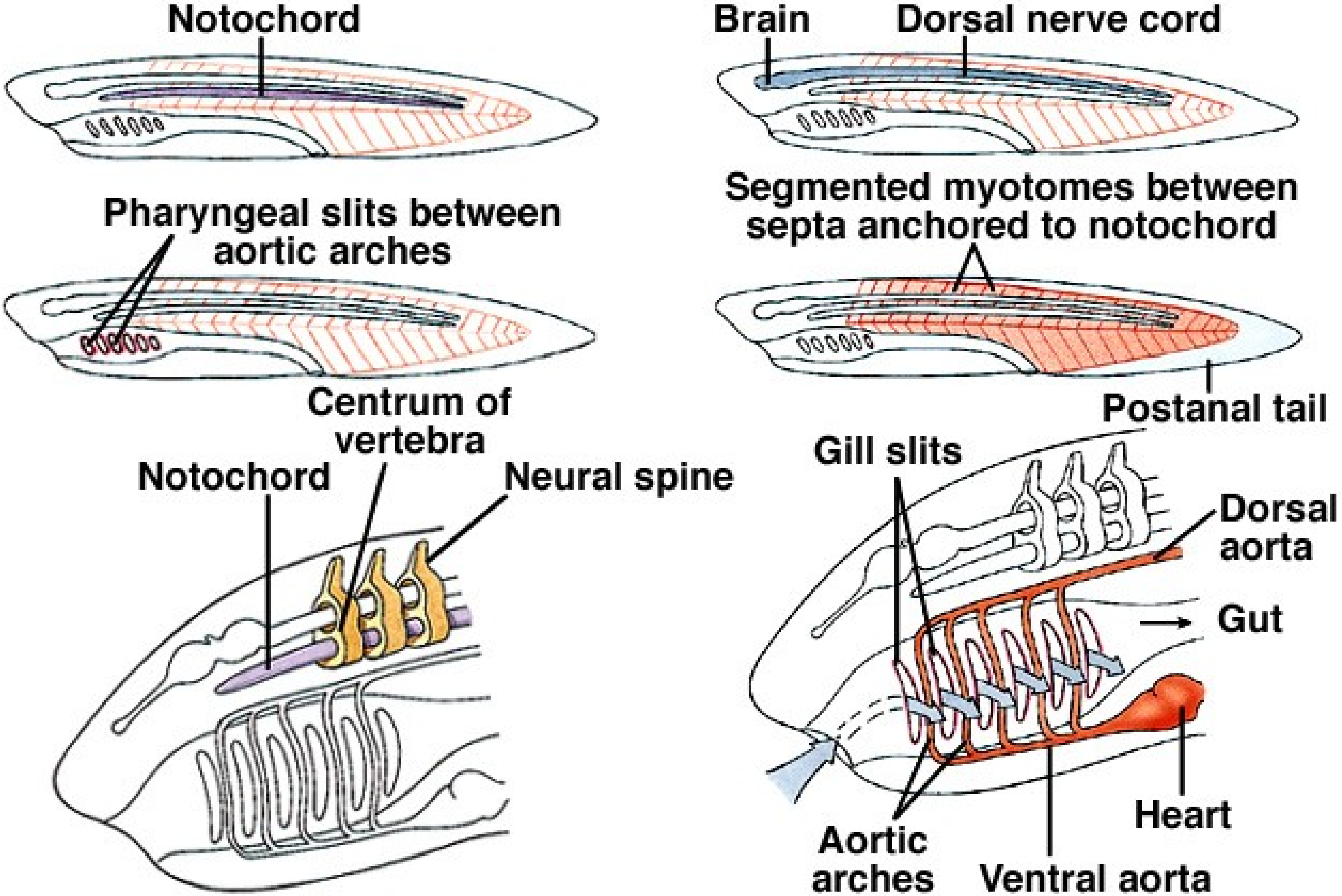
Characteristics of chordates



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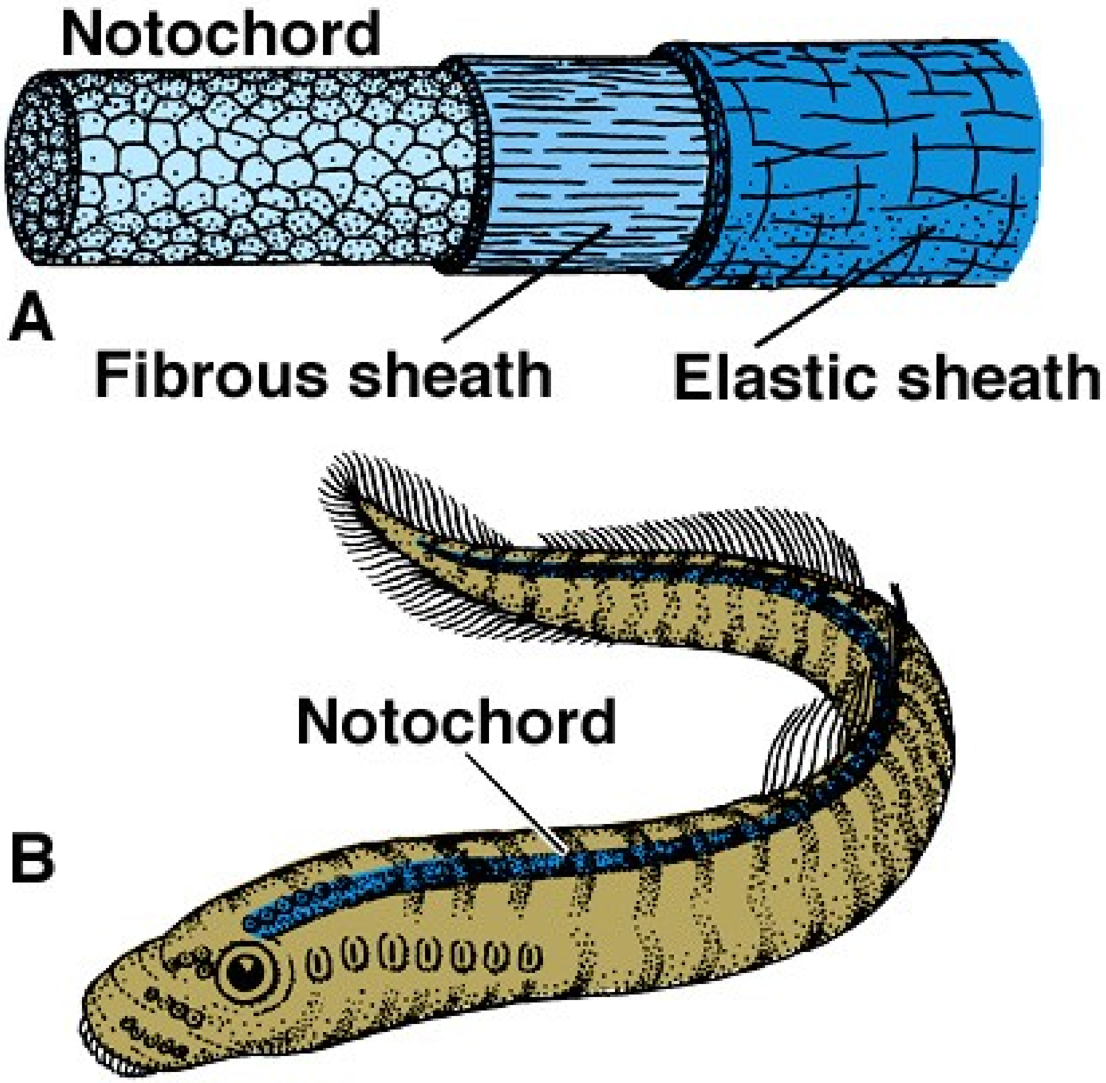
Structure of the notochord



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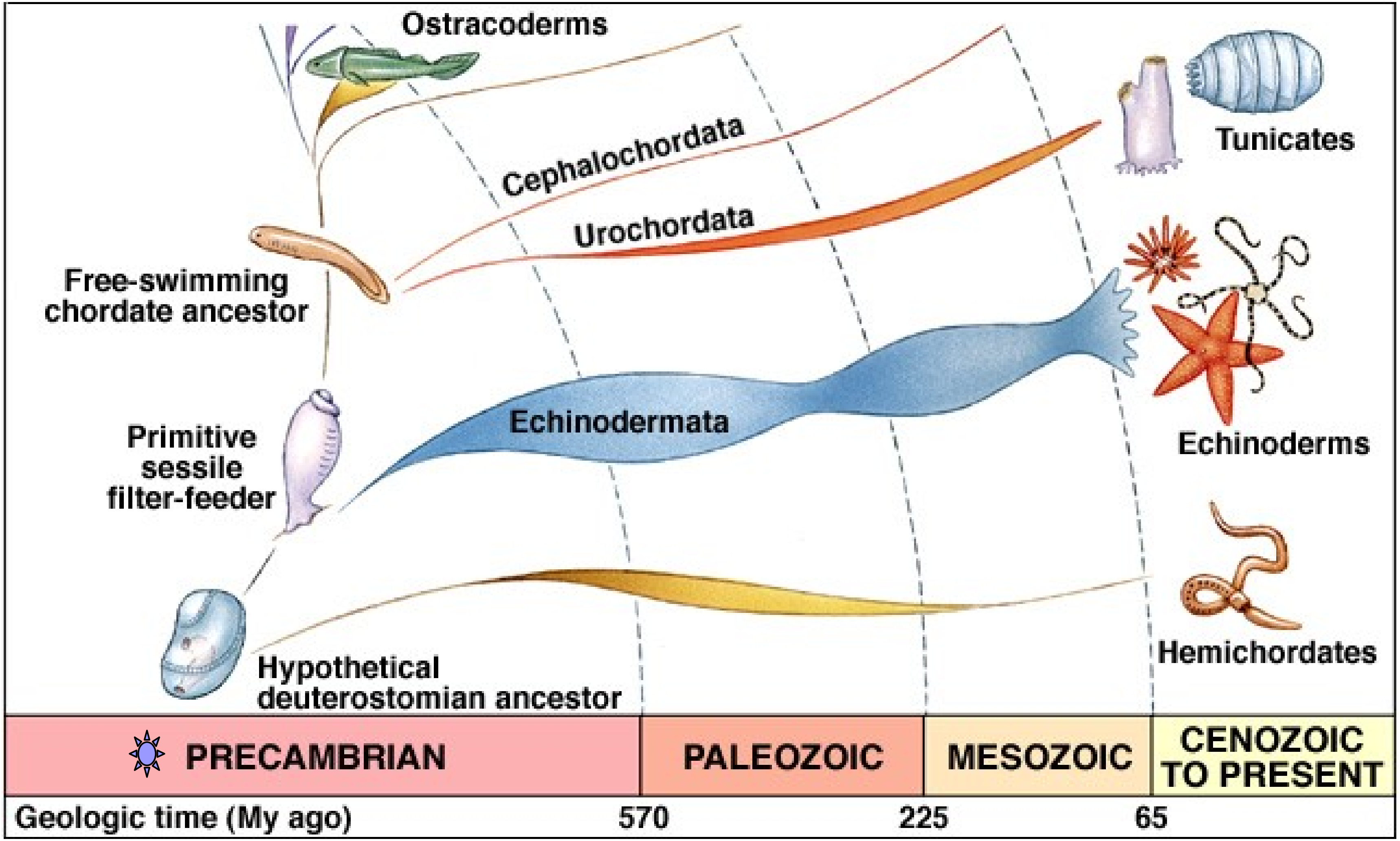
Phylogenetic tree of chordates (II)



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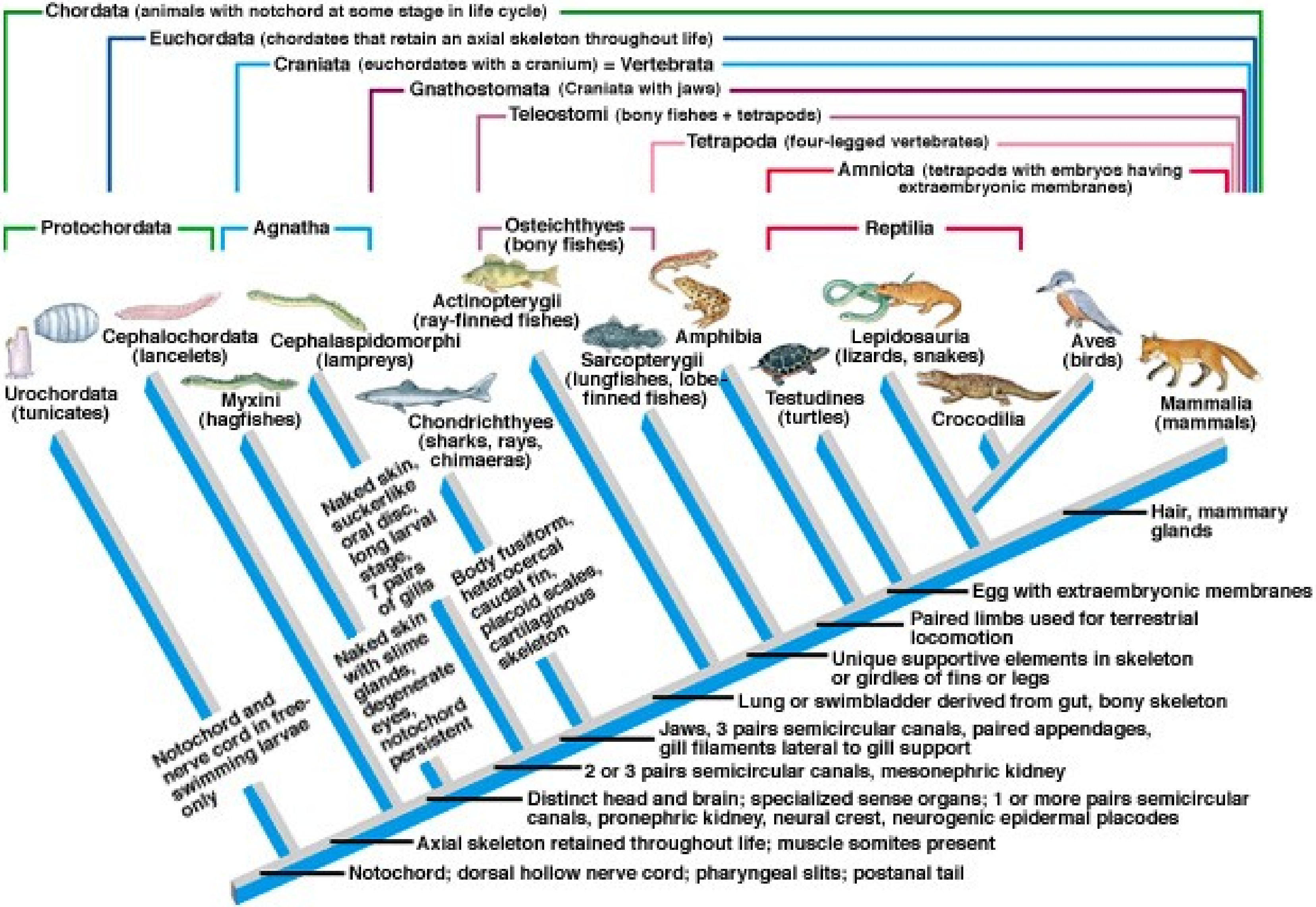
Cladogram of chordates

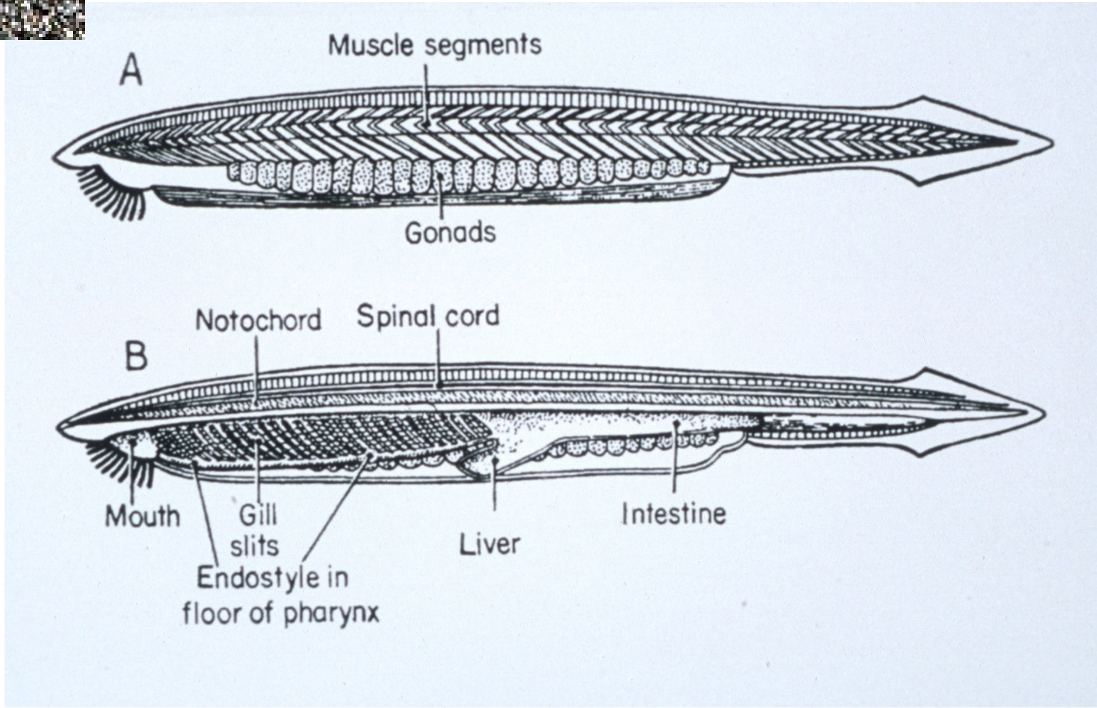

Chordata (animals with notochord at some stage in life cycle)
Euchordata (chordates that retain an axial skeleton throughout life)
Craniata (euchordates with a cranium) = Vertebrata
Gnathostomata (Craniata with jaws)
Teleostomi (bony fishes + tetrapods)
Tetrapoda (four-legged vertebrates)
Amniota (tetrapods with embryos having extraembryonic membranes)
Protochordata
Agnatha
Osteichthyes (bony fishes)
Reptilia
Urochordata (tunicates)
Cephalochordata (lancelets)
Myxini (hagfishes)
Cephalaspidomorphi (lampreys)
Chondrichthyes (sharks, rays, chimaeras)
Actinopterygii (ray-finned fishes)
Sarcopterygii (lungfishes, lobe-finned fishes)
Amphibia
Testudines (turtles)
Lepidosauria (lizards, snakes)
Crocodilia
Aves (birds)
Mammalia (mammals)
Notochord and nerve cord in free-swimming larvae only
Naked skin with slime glands, degenerate eyes, notochord persistent
Naked skin, suckerlike oral disc, long larval stage, 7 pairs of gills
Body fusiform, heterocercal caudal fin, placoid scales, cartilaginous skeleton
Hair, mammary glands
Egg with extraembryonic membranes
Paired limbs used for terrestrial locomotion
Unique supportive elements in skeleton or girdles of fins or legs
Lung or swimbladder derived from gut, bony skeleton
Jaws, 3 pairs semicircular canals, paired appendages, gill filaments lateral to gill support
2 or 3 pairs semicircular canals, mesonephric kidney
Distinct head and brain; specialized sense organs; 1 or more pairs semicircular canals, pronephric kidney, neural crest, neurogenic epidermal placodes
Axial skeleton retained throughout life; muscle somites present
Notochord; dorsal hollow nerve cord; pharyngeal slits; postanal tail

Subphylum Cephalochordata

- Lancelets
- 26 species
- All marine filter feeders
- Characteristics as for the phylum
- Gas exchange across body surface
- Usually sessile but can leave burrow and swim

1. **Notochord**
2. **Dorsal hollow nerve cord**
3. **Pharyngeal slits**
4. **Endostyle**
5. **Post-anal tail**

Branchiostoma (Amphioxus)



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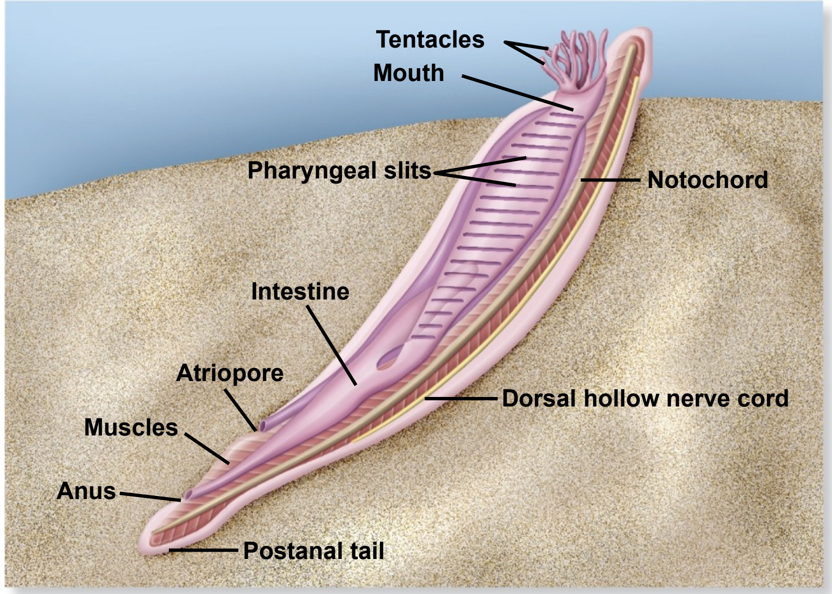
(a) Lancelet in the sand



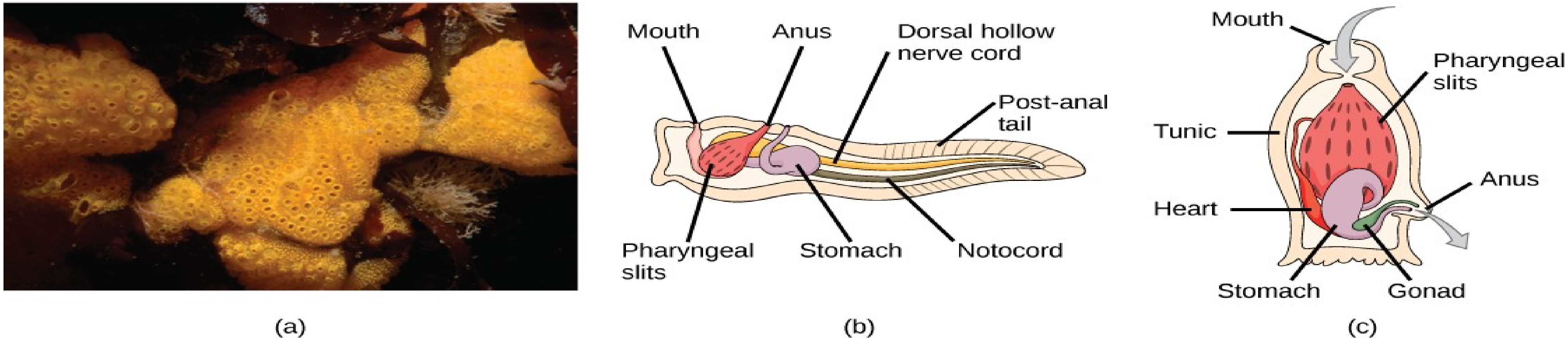
(b) Body plan of the lancelet

a: © Natural Visions/Alamy

Subphylum Urochordata

- **Tunicates** – animal encased in tunic or test
- 3,000 marine species
- Adult is sessile with only pharyngeal slits
- Larvae tadpole-like exhibiting all 5 chordate hallmarks
- Urochordates are closest living relatives of vertebrates
  - Cephalochordates like lancelet more closely related to echinoderms
- Filter feeders with two siphons

Figure 29.4



- (a) This photograph shows a colony of the tunicate *Botrylloides violaceus*. (b) The larval stage of the tunicate possesses all of the features characteristic of chordates: a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail. (c) In the adult stage, the notochord, nerve cord, and tail disappear. (credit: modification of work by Dann Blackwood, USGS)

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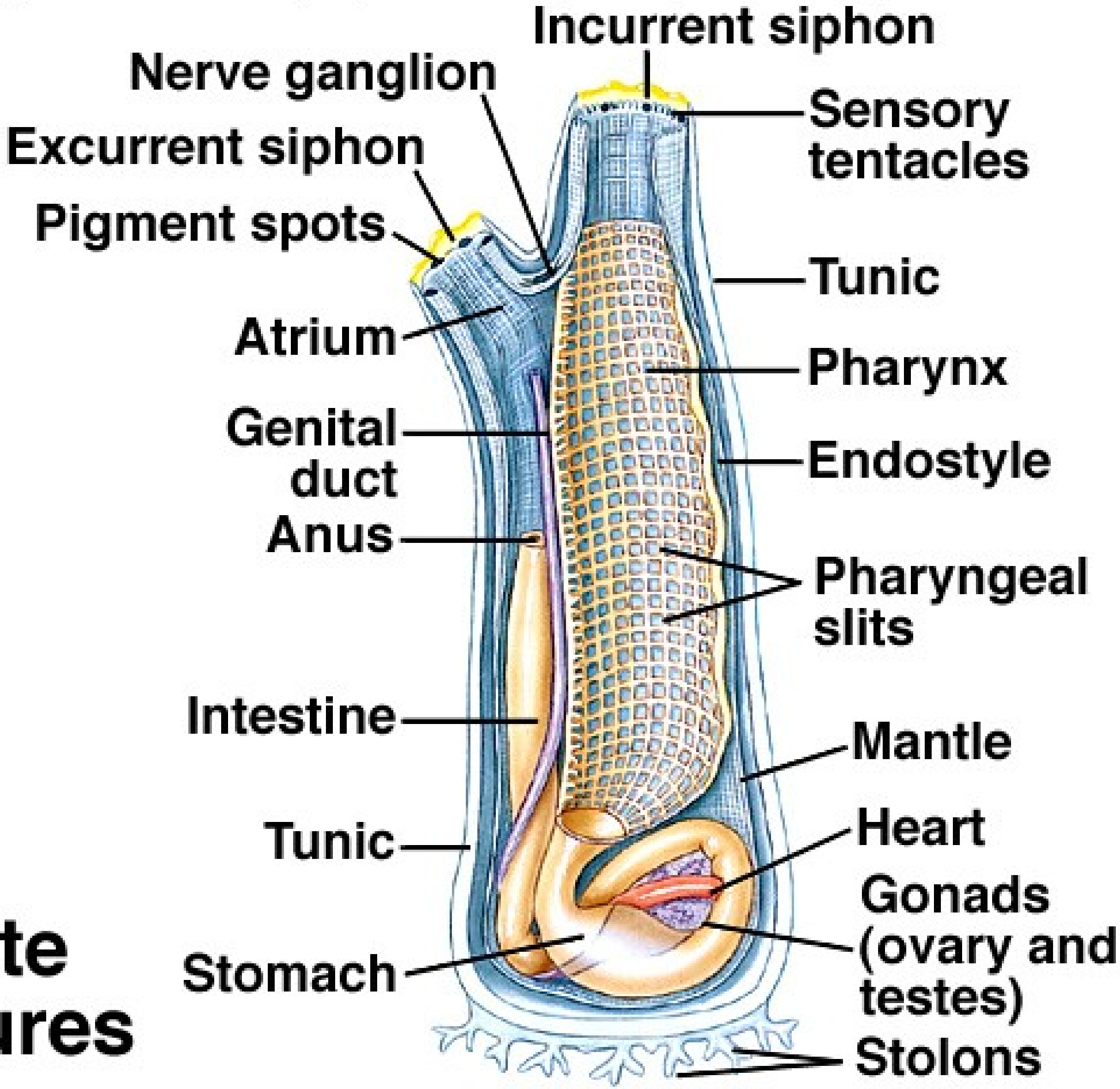
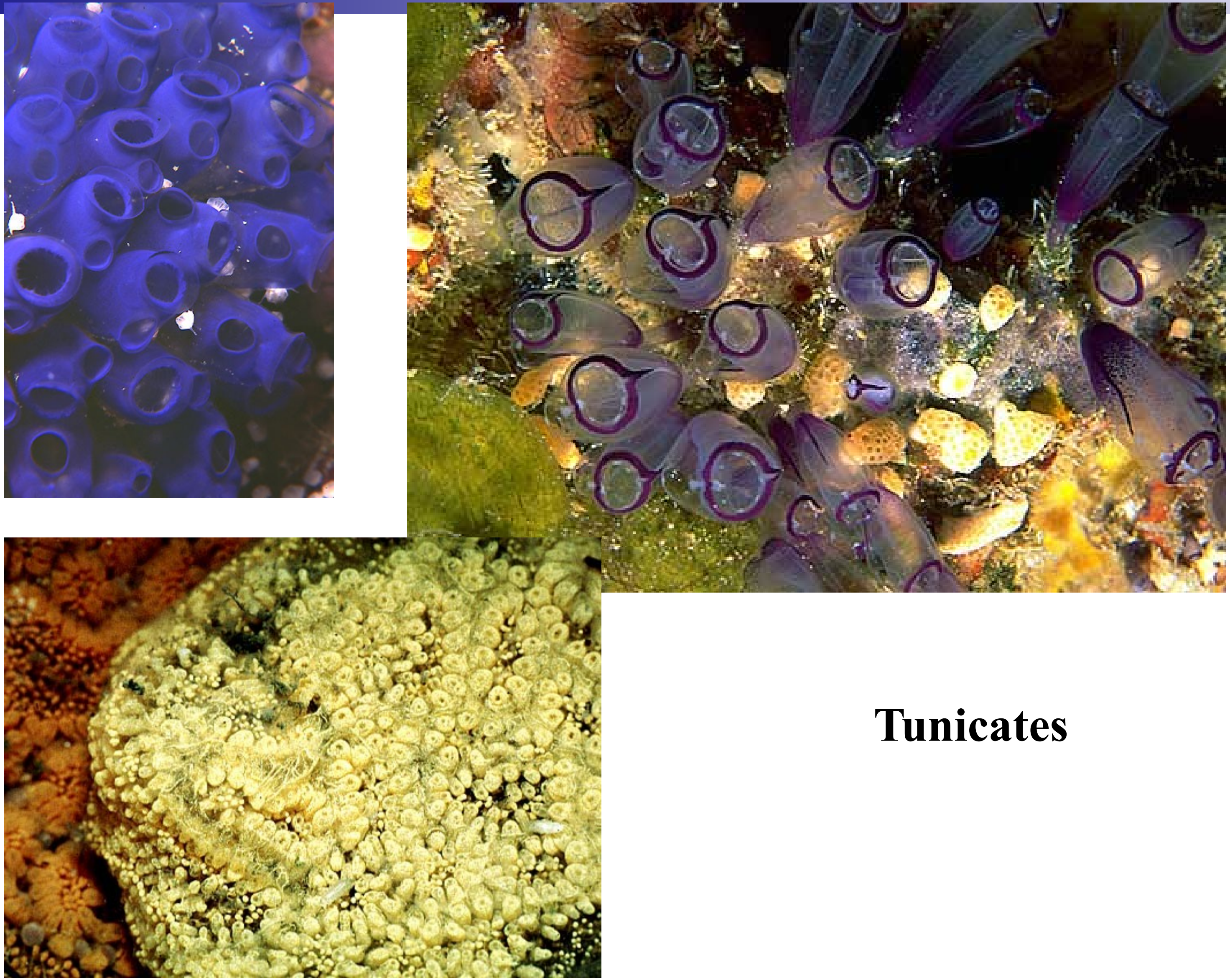


Tunicate structures



Tunicates

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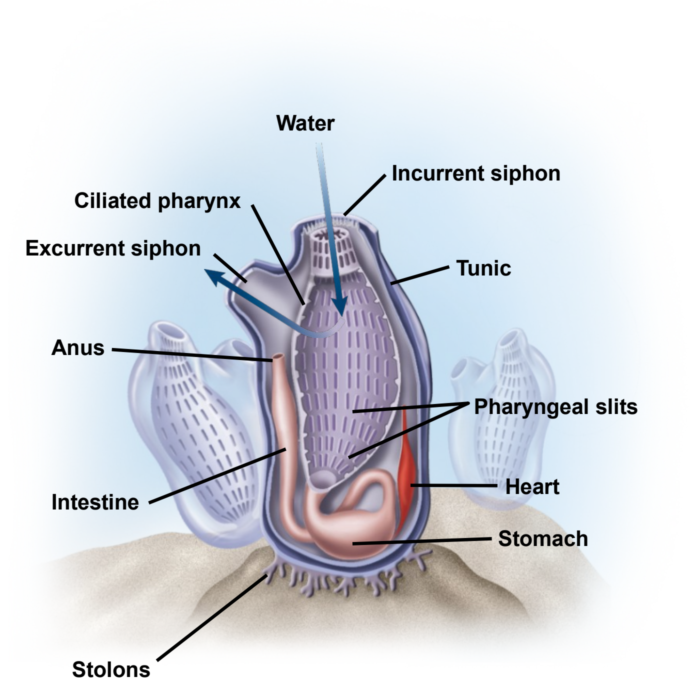
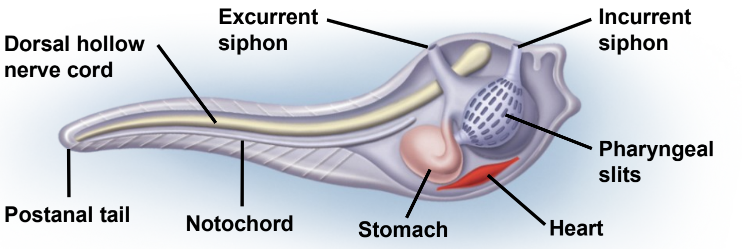


(a) Adult tunicate

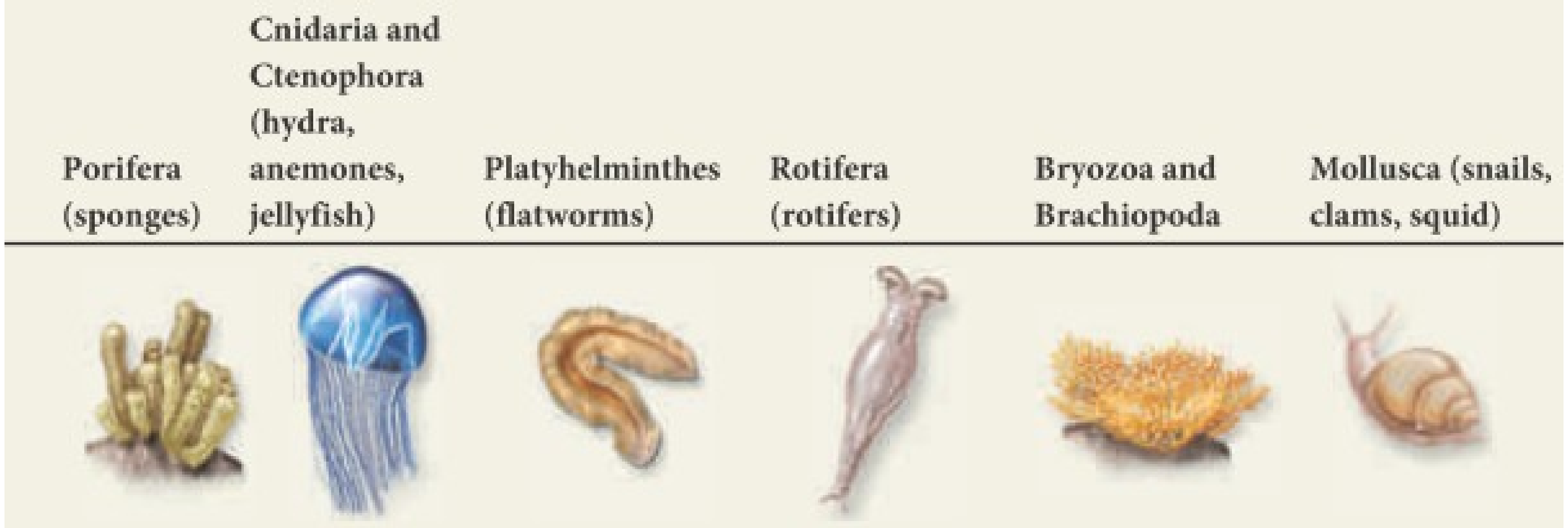


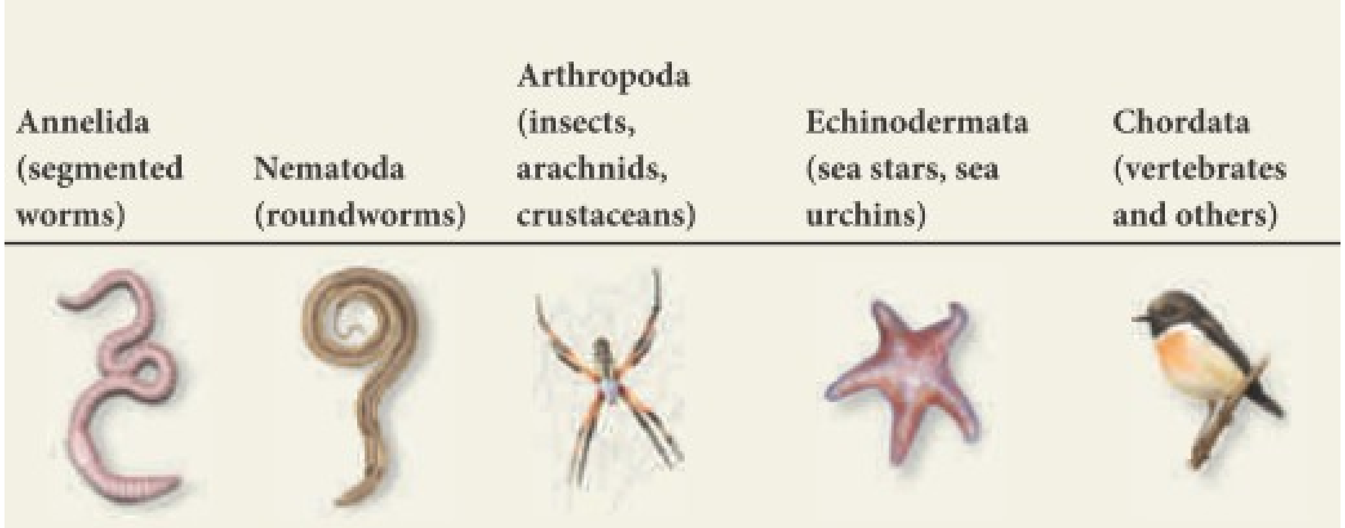
(b) The larval form of the tunicate

(c) Typical tunicate

c: © Reinhard Dirscherl/Visuals Unlimited.

- Rudimentary circulatory system
- Simple nervous system
- Mostly hermaphroditic


Porifera (sponges)
Cnidaria and Ctenophora (hydra, anemones, jellyfish)
Platyhelminthes (flatworms)
Rotifera (rotifers)
Bryozoa and Brachiopoda
Mollusca (snails, clams, squid)


Annelida (segmented worms)
Nematoda (roundworms)
Arthropoda (insects, arachnids, crustaceans)
Echinodermata (sea stars, sea urchins)
Chordata (vertebrates and others)

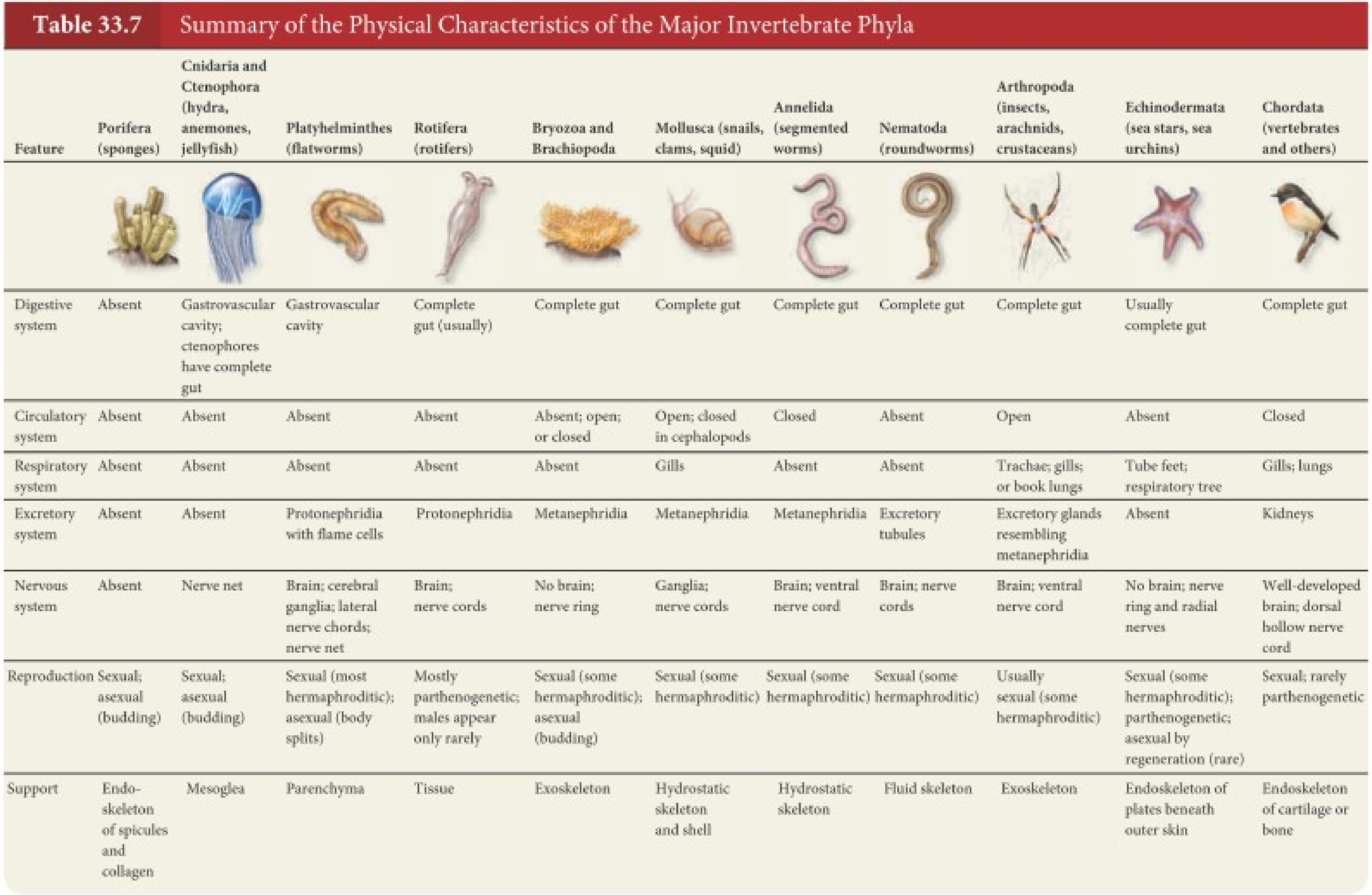


Table 33.7 Summary of the Physical Characteristics of the Major Invertebrate Phyla

Feature	Porifera (sponges)	Cnidaria and Ctenophora (hydra, anemones, jellyfish)	Platyhelminthes (flatworms)	Rotifera (rotifers)	Bryozoa and Brachiopoda	Mollusca (snails, clams, squid)	Annelida (segmented worms)	Nematoda (roundworms)	Arthropoda (insects, arachnids, crustaceans)	Echinodermata (sea stars, sea urchins)	Chordata (vertebrates and others)
Digestive system	Absent	Gastrovascular cavity; ctenophores have complete gut	Gastrovascular cavity	Complete gut (usually)	Complete gut	Complete gut	Complete gut	Complete gut	Complete gut	Usually complete gut	Complete gut
Circulatory system	Absent	Absent	Absent	Absent	Absent; open; or closed	Open; closed in cephalopods	Closed	Absent	Open	Absent	Closed
Respiratory system	Absent	Absent	Absent	Absent	Absent	Gills	Absent	Absent	Trachae; gills; or book lungs	Tube feet; respiratory tree	Gills; lungs
Excretory system	Absent	Absent	Protonephridia with flame cells	Protonephridia	Metanephridia	Metanephridia	Metanephridia	Excretory tubules	Excretory glands resembling metanephridia	Absent	Kidneys
Nervous system	Absent	Nerve net	Brain; cerebral ganglia; lateral nerve chords; nerve net	Brain; nerve cords	No brain; nerve ring	Ganglia; nerve cords	Brain; ventral nerve cord	Brain; nerve cords	Brain; ventral nerve cord	No brain; nerve ring and radial nerves	Well-developed brain; dorsal hollow nerve cord
Reproduction	Sexual; asexual (budding)	Sexual; asexual (budding)	Sexual (most hermaphroditic); asexual (body splits)	Mostly parthenogenetic; males appear only rarely	Sexual (some hermaphroditic); asexual (budding)	Sexual (some hermaphroditic)	Sexual (some hermaphroditic)	Sexual (some hermaphroditic)	Usually sexual (some hermaphroditic)	Sexual (some hermaphroditic); parthenogenetic; asexual by regeneration (rare)	Sexual; rarely parthenogenetic
Support	Endoskeleton of spicules and collagen	Mesoglea	Parenchyma	Tissue	Exoskeleton	Hydrostatic skeleton and shell	Hydrostatic skeleton	Fluid skeleton	Exoskeleton	Endoskeleton of plates beneath outer skin	Endoskeleton of cartilage or bone

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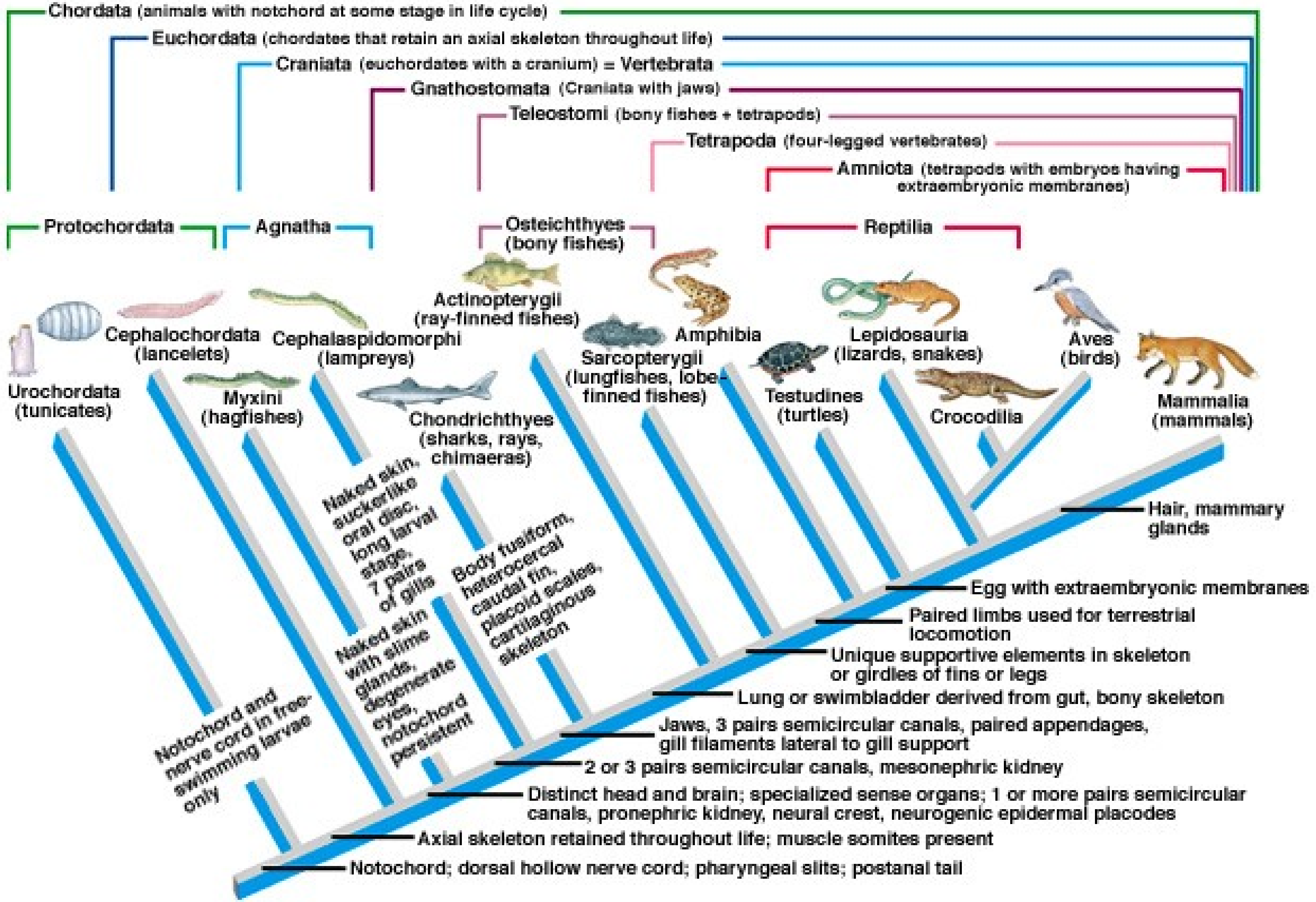
Cladogram of chordates



Chordata (animals with notchord at some stage in life cycle)

Euchordata (chordates that retain an axial skeleton throughout life)

Craniata (euchordates with a cranium) = Vertebrata

Gnathostomata (Craniata with jaws)

Teleostomi (bony fishes + tetrapods)

Tetrapoda (four-legged vertebrates)

Amniota (tetrapods with embryos having extraembryonic membranes)

Protochordata

Agnatha

Osteichthyes (bony fishes)

Reptilia

Urochordata (tunicates)

Cephalochordata (lancelets)

Myxini (hagfishes)

Cephalaspidomorphi (lampreys)

Chondrichthyes (sharks, rays, chimaeras)

Actinopterygii (ray-finned fishes)

Sarcopterygii (lungfishes, lobe-finned fishes)

Amphibia

Testudines (turtles)

Lepidosauria (lizards, snakes)

Crocodilia

Aves (birds)

Mammalia (mammals)

Notochord and nerve cord in free-swimming larvae only

Naked skin with slime glands, degenerate eyes, notochord persistent

Naked skin, suckerlike oral disc, long larval stage, 7 pairs of gills

Body fusiform, heterocercal caudal fin, placoid scales, cartilaginous skeleton

Hair, mammary glands

Egg with extraembryonic membranes

Paired limbs used for terrestrial locomotion

Unique supportive elements in skeleton or girdles of fins or legs

Lung or swimbladder derived from gut, bony skeleton

Jaws, 3 pairs semicircular canals, paired appendages, gill filaments lateral to gill support

2 or 3 pairs semicircular canals, mesonephric kidney

Distinct head and brain; specialized sense organs; 1 or more pairs semicircular canals, pronephric kidney, neural crest, neurogenic epidermal placodes

Axial skeleton retained throughout life; muscle somites present

Notochord; dorsal hollow nerve cord; pharyngeal slits; postanal tail

CRANIATA – THE Craniates: Animals with skulls

These are the animals that you are probably the most familiar with. There are > 53,000 species of craniate. With the exception of the HAGFISH, all craniates are also VERTEBRATES – ANIMALS WITH BACKBONES

Characteristics

The same as the phylum Chordata, +

- **Endoskeleton of CARTILAGE or BONE, with a vertebral column that surrounds the dorsal nerve cord. Two pairs of limbs or fins in all except the jawless fish.**
- **Notochord only present during embryonic development**
- **Closed circulatory system with ventral heart of 2-4 chambers**

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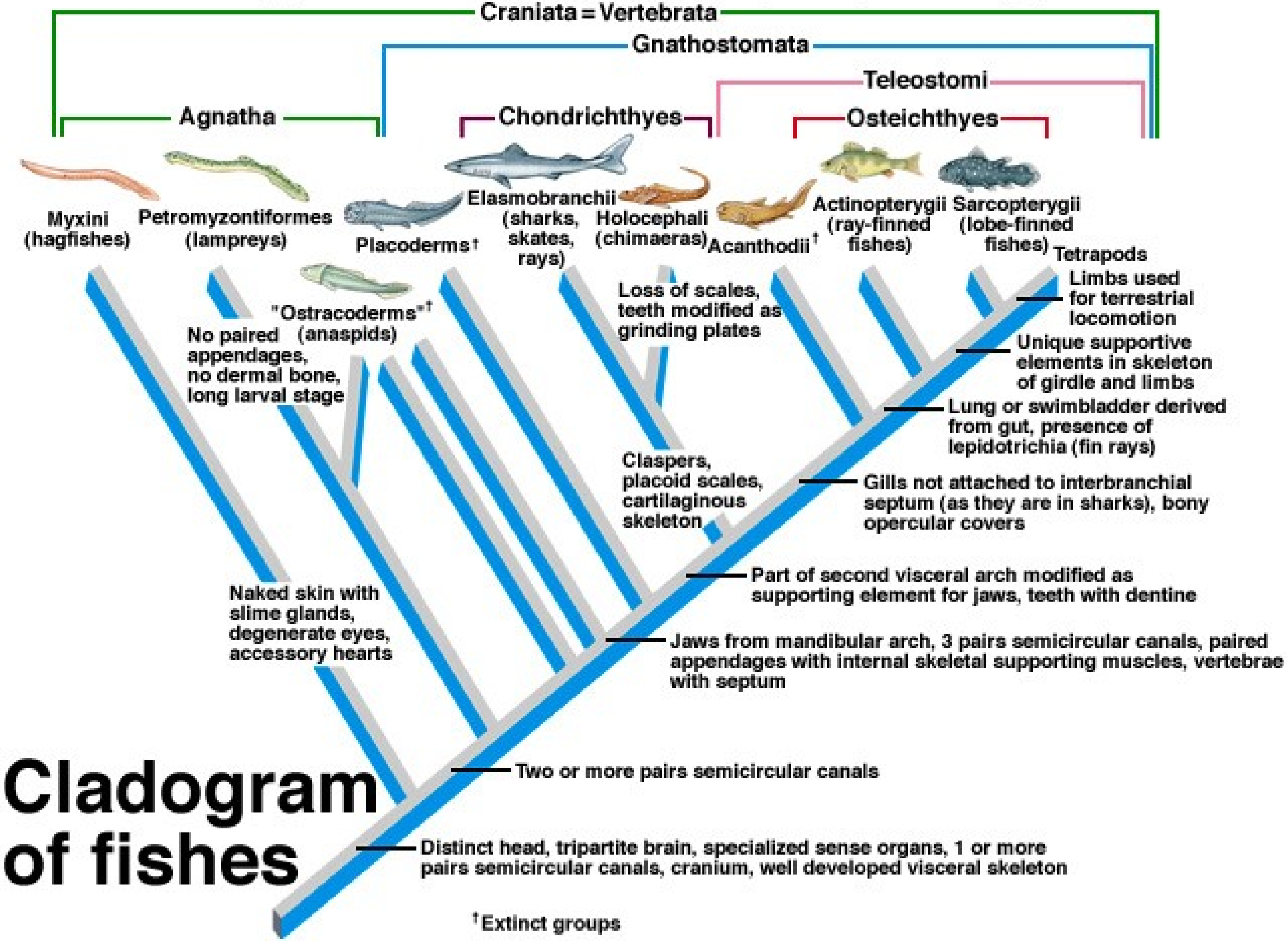
Cladogram of fishes



Craniata = Vertebrata

Gnathostomata

Teleostomi

Agnatha

Chondrichthyes

Osteichthyes

Myxini (hagfishes)

Petromyzontiformes (lampreys)

"Ostracoderms"† (anaspids)

Placoderms†

Elasmobranchii (sharks, skates, rays)

Holocephali (chimaeras)

Acanthodii†

Actinopterygii (ray-finned fishes)

Sarcopterygii (lobe-finned fishes)

Tetrapods

No paired appendages, no dermal bone, long larval stage

Naked skin with slime glands, degenerate eyes, accessory hearts

Loss of scales, teeth modified as grinding plates

Claspers, placoid scales, cartilaginous skeleton

Limbs used for terrestrial locomotion

Unique supportive elements in skeleton of girdle and limbs

Lung or swimbladder derived from gut, presence of lepidotrichia (fin rays)

Gills not attached to interbranchial septum (as they are in sharks), bony opercular covers

Part of second visceral arch modified as supporting element for jaws, teeth with dentine

Jaws from mandibular arch, 3 pairs semicircular canals, paired appendages with internal skeletal supporting muscles, vertebrae with septum

Two or more pairs semicircular canals

Distinct head, tripartite brain, specialized sense organs, 1 or more pairs semicircular canals, cranium, well developed visceral skeleton

†Extinct groups

Ancestry and Relationships of Major Groups of Fishes

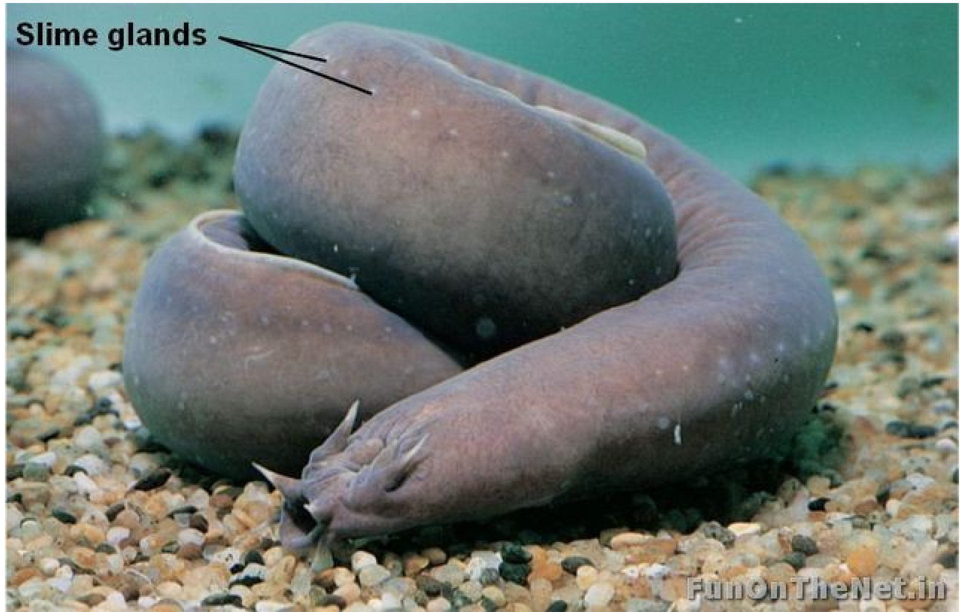
- Agnathans – “No jaws”
  - Include living hagfishes and lampreys
    - *Hagfishes* lack vertebrae
    - *Lampreys* have rudimentary vertebrae

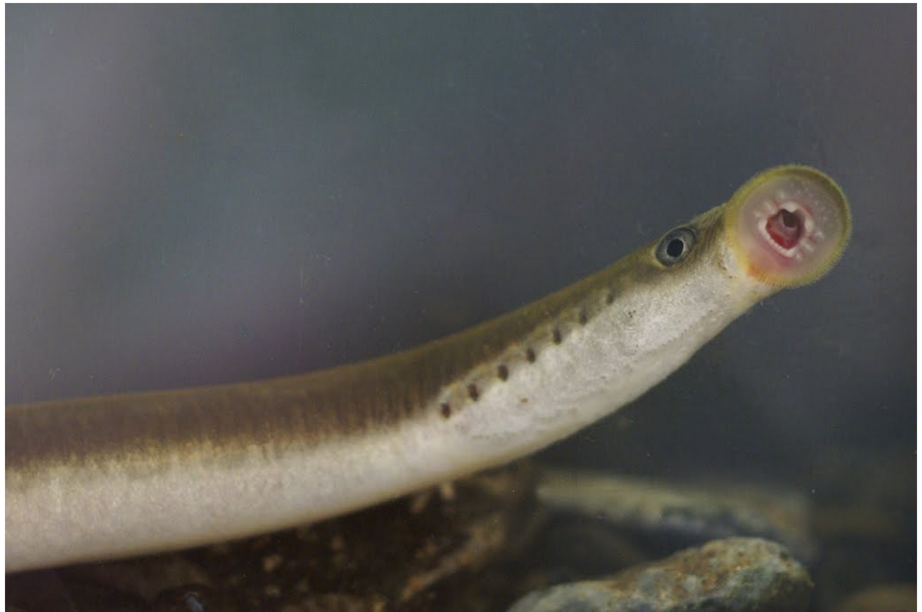
  - Included in *subphylum Vertebrata* because they have a cranium
  - Although they look very similar and are both jawless, hagfish branched off from the ancestral group long before modern lampreys arose.

Living Jawless Fishes

Overview

- Living jawless fishes include *hagfishes and lampreys*
    - Members of both groups *lack jaws, no internal bone, no scales, no paired fins*
    - Both groups share porelike gill openings and an eel-like body





Class Myxini

- **Hagfish**
- Jawless marine fish that lack vertebrae (but have a skull)
- Notochord and a cartilaginous skull
- Essentially blind but with a keen sense of smell
- Copious amounts of **slime**

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Pat Morris/ardea.com

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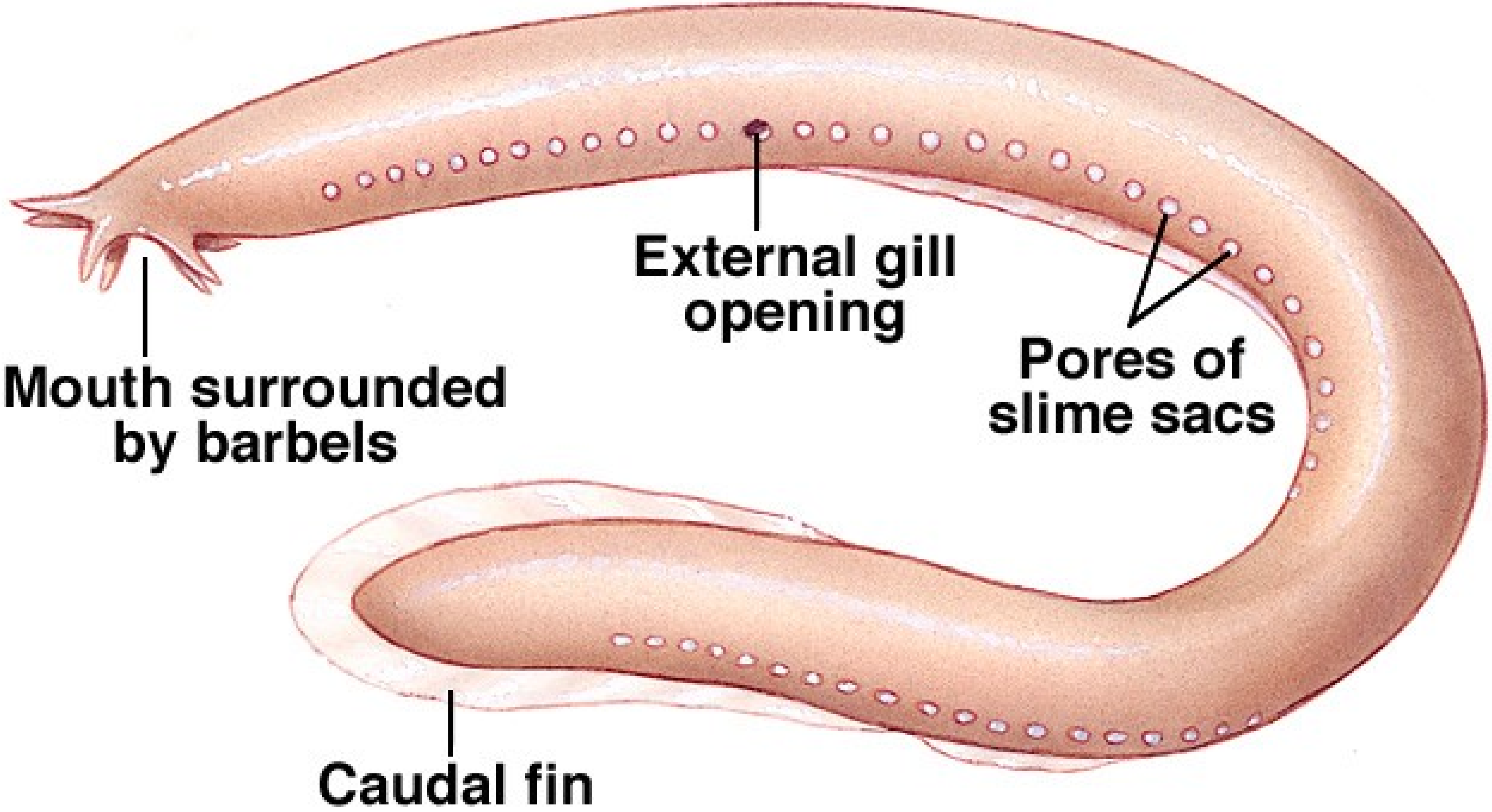
The Atlantic hagfish *(Myxine)*

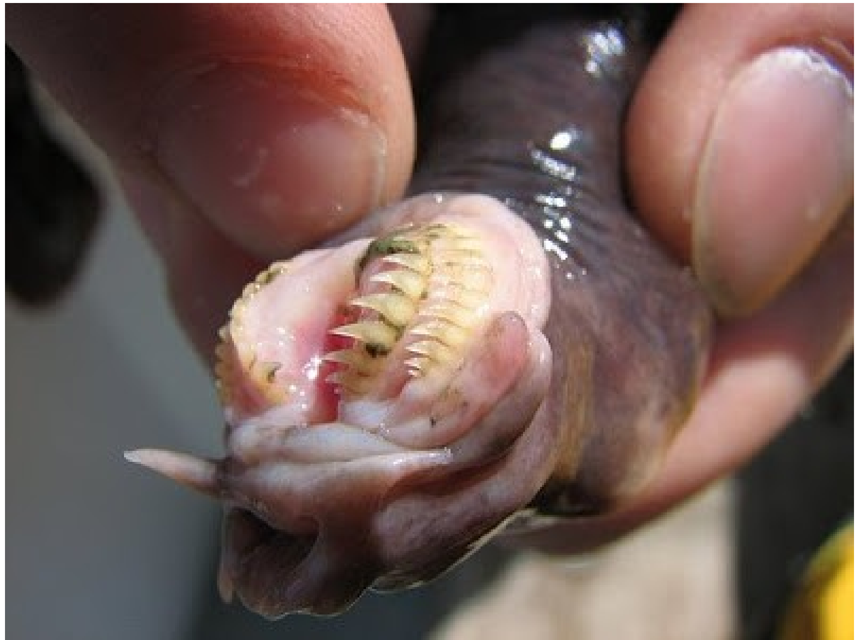
NOT a vertebrate, but a craniate



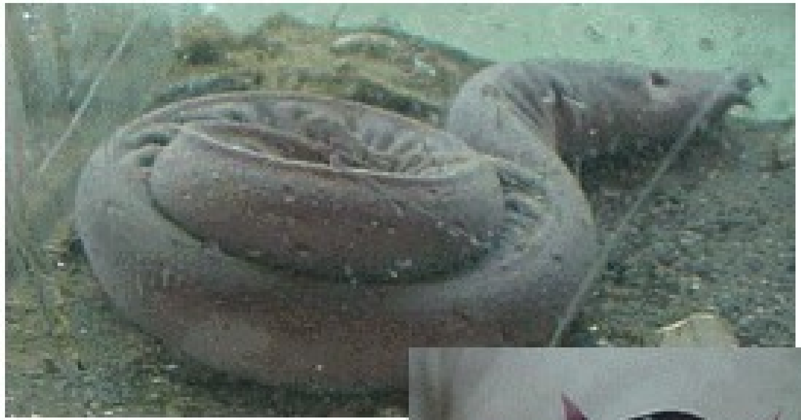
Living Jawless Fishes

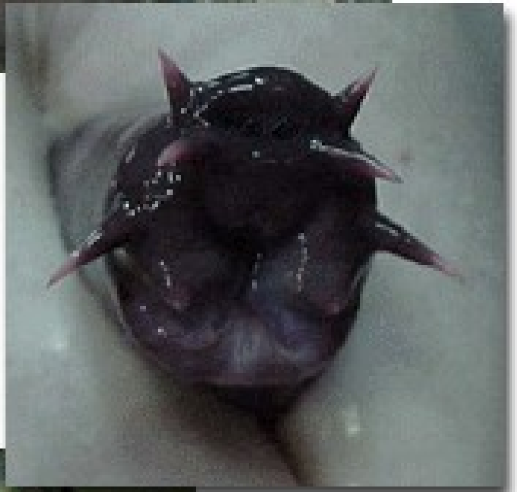
Hagfishes

- Entirely marine
- Scavengers and predators of annelids, molluscs, dead or dying fishes, etc.
- Enters dead or dying animal through orifice (hole) or by digging inside using keratinized plates on tongue



- Nearly blind
    - Locate food by an acute sense of smell and touch
- To provide leverage
    - Ties knot in tail and passes it forward to press against prey
- Special glands along body secrete fluid that becomes slimy in contact with seawater
- Hagfish video
- Body fluids the same as seawater

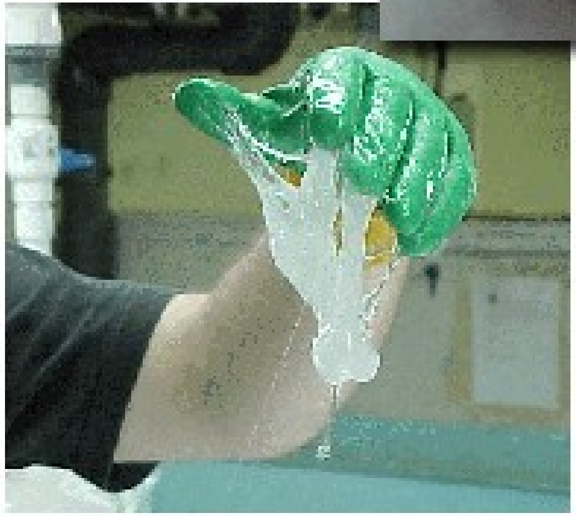




Above: Hagfish resting in a tank.

Left: Hagfish face. A ring of sensitive tentacles surround the hagfish's mouth.

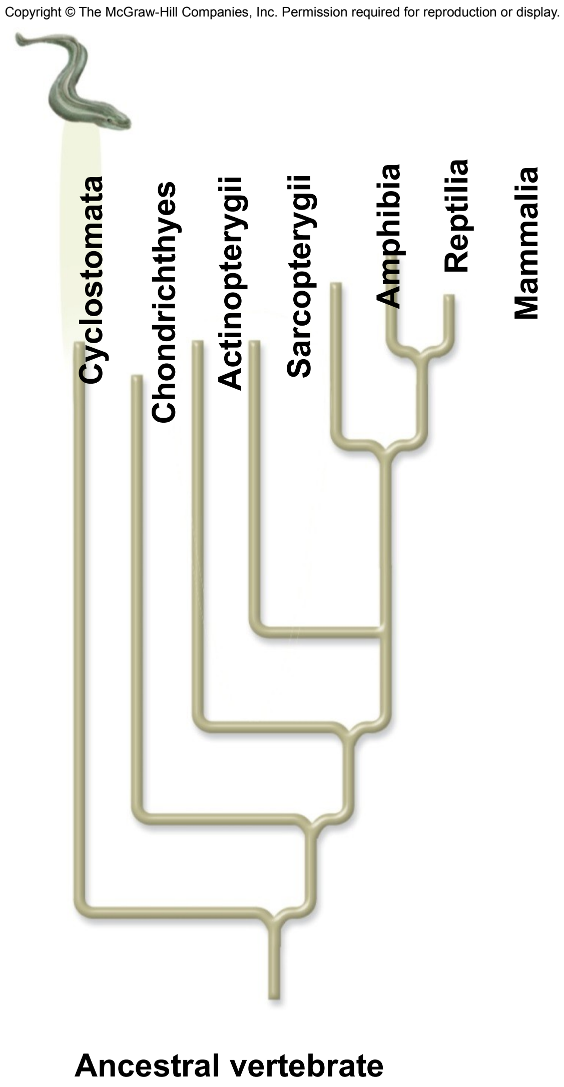
Below: Researcher holds up a handful of hagfish slime, a defensive mechanism for this animal.



Source:
Oceanlink.island.net

Class Petromyzontida (Hyperoartia)

- **Lampreys**
- Lack hinged jaw and true appendages
    - **Agnathan = jawless**
- Have a notochord and rudimentary vertebral column



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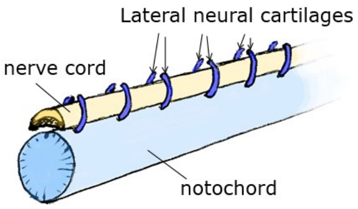

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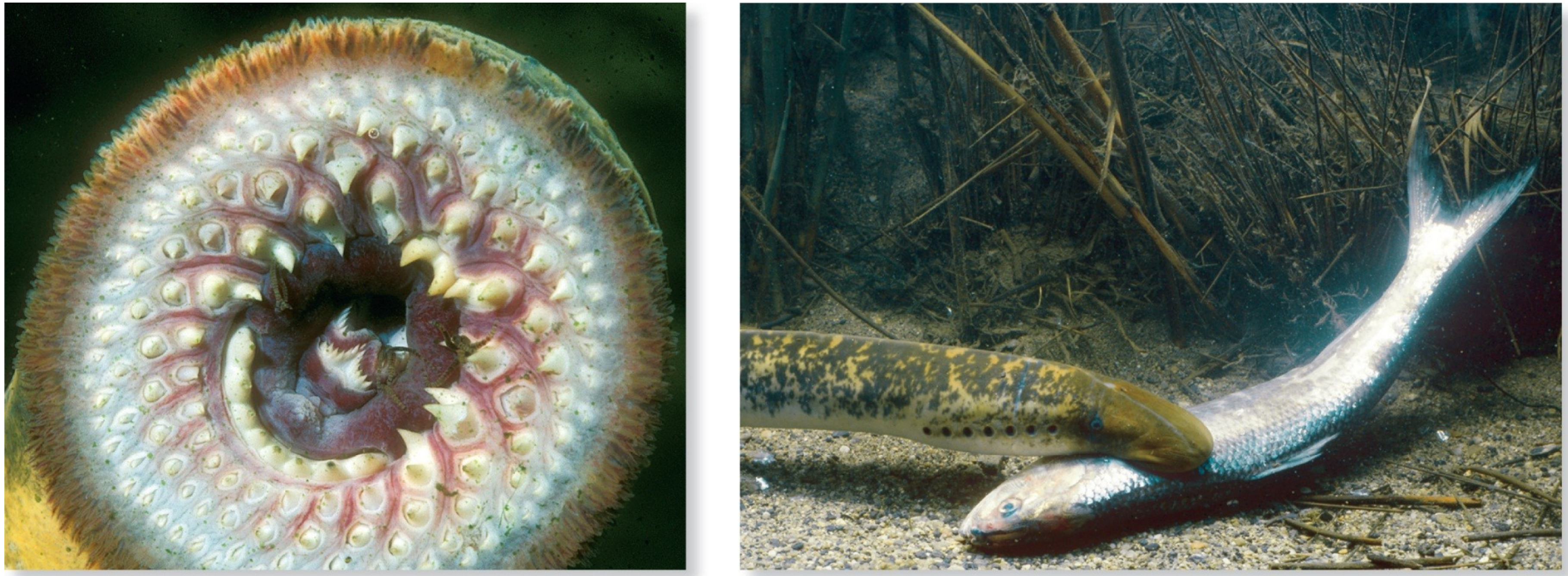


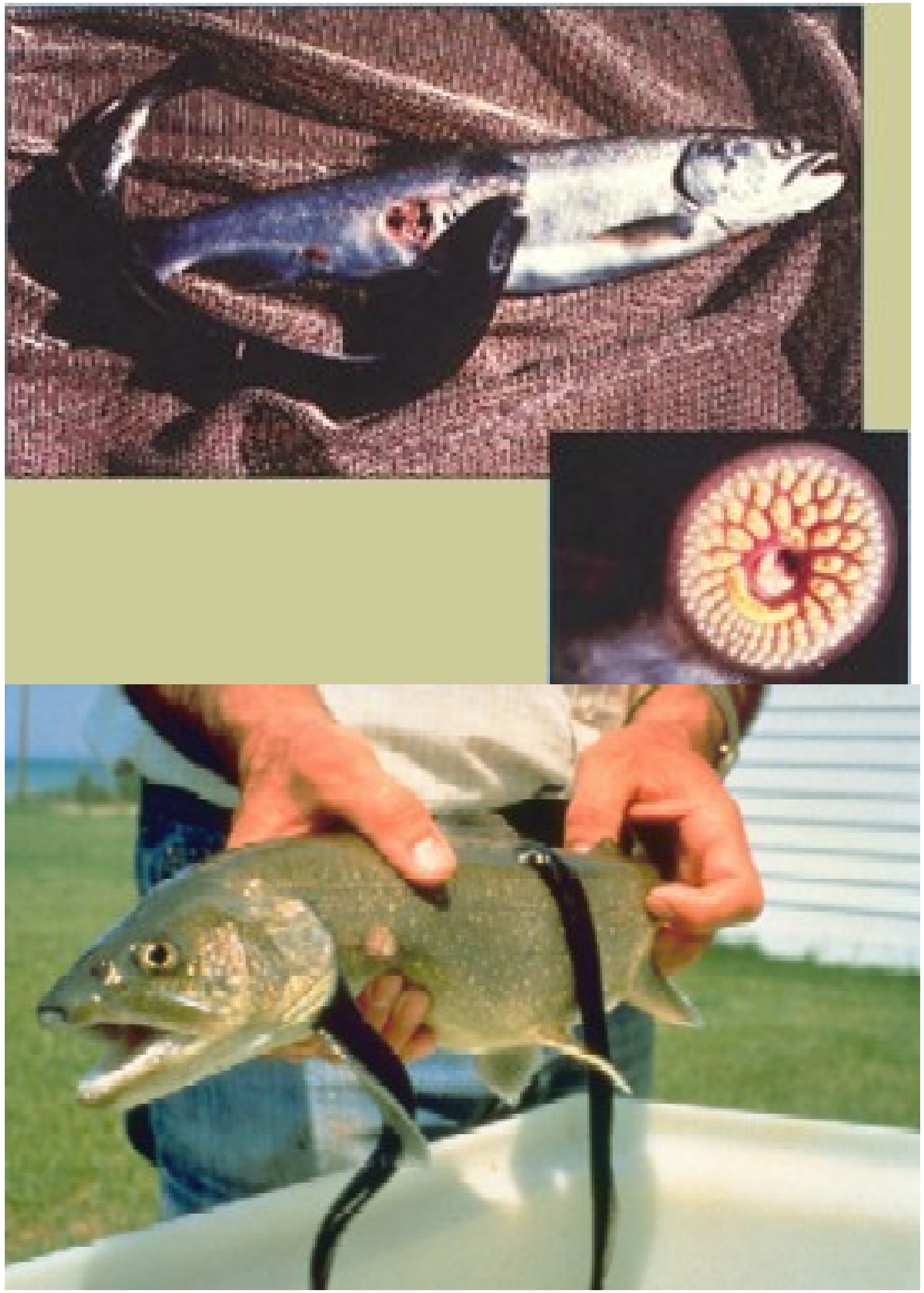
(a) Jawless mouth of a sea lamprey **(b) A sea lamprey feeding**

a: © Breck P. Kent/ Animals Animals; b: © Jacana/Photo Researchers, Inc.

- One of earliest diverging groups of vertebrates
- Found in marine and freshwater
- Marine lampreys **parasitic** as adults

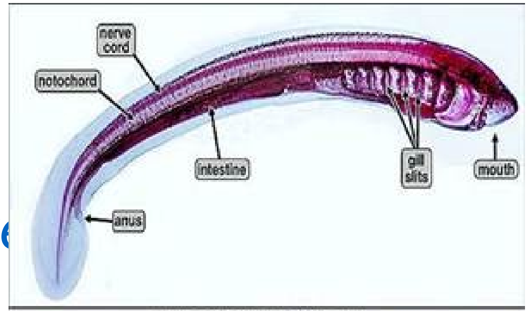
Living Jawless Fishes

- *Parasitic Lampreys*
  - Marine, parasitic lampreys migrate to the sea
  - Other species remain in freshwater
  - Attach to a fish by a sucker-like mouth
  - Sharp teeth rasp through flesh as they suck fluids
  - Inject anticoagulant into a wound
  - When engorged, lamprey drops off but *wound may be fatal to fish*
  - *Parasitic freshwater adults* live 1–2 years before spawning and dying



Living Jawless Fishes

- *Reproduction and Development*
  - Ascend freshwater streams to breed
  - In North America
    - All spawn in winter or spring
  - Males build nest by lifting stones with oral discs and using body vibrations
  - As eggs are shed into nest, the male fertilizes them
  - Adults die soon after spawning
  - Eggs hatch in two weeks into *ammoceot* *larvae*
    - Suspension-feeder until it metamorphoses into an adult



Ammocoetes larva of a lamprey

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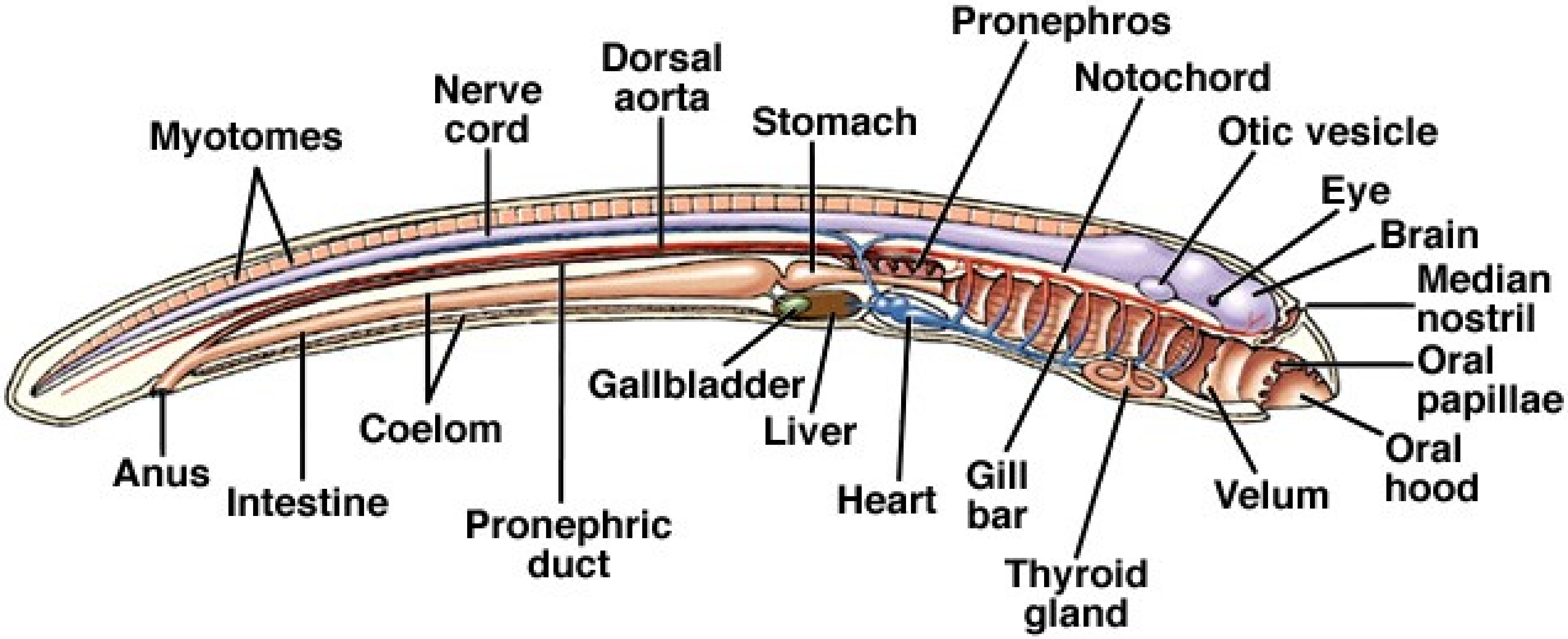
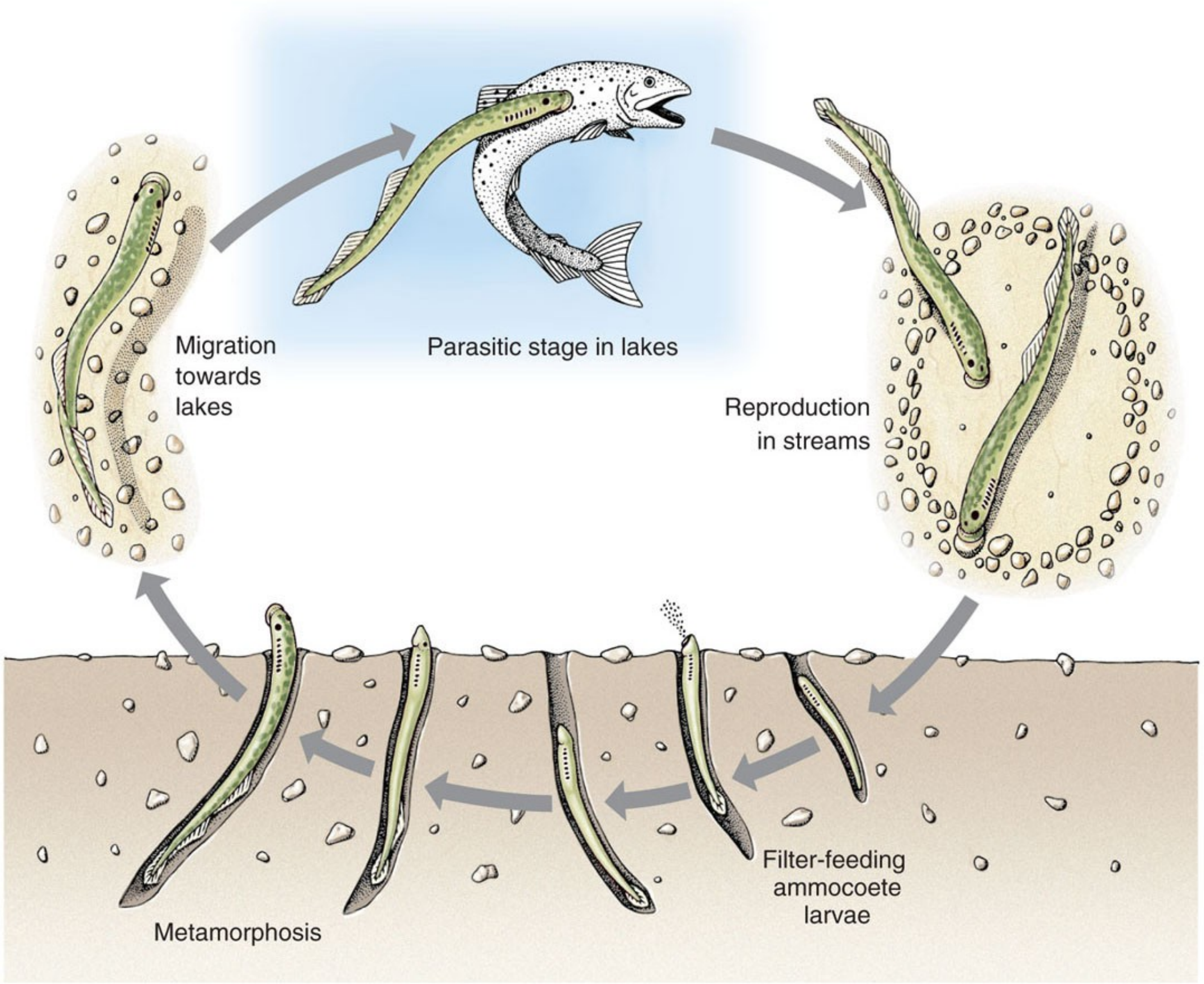
Ammocoete larva




Parasitic stage in lakes
Reproduction in streams
Filter-feeding ammocoete larvae
Metamorphosis
Migration towards lakes

Living Jawless Fishes

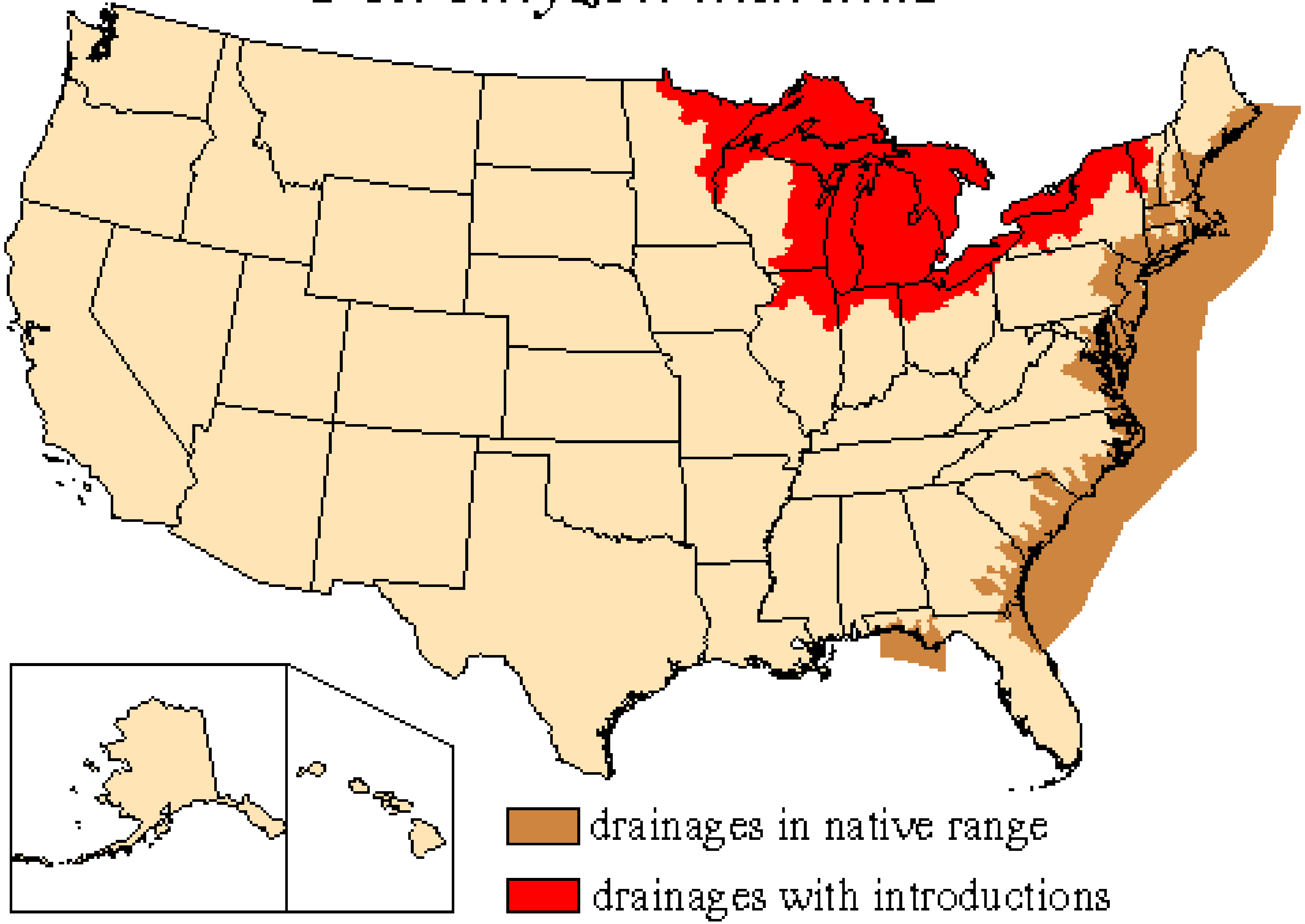
- *Nonparasitic lampreys* do not feed as adults
  - Digestive tract degenerates as an adult
  - They spawn and die

Living Jawless Fishes

- *Sea Lamprey Invasion of the Great Lakes Region*
  - No lampreys were in the U. S. Great Lakes west of Niagara Falls until the Well and Ship Canal was deepened between 1913 and 1918
  - Sea lampreys moved first through Lake Erie to Lakes Huron, Michigan, and Superior
  - Lampreys prefer to eat lake trout
    - *Destroyed this commercial species along with overfishing*
    - *Lake trout are recovering due to a Restocking program*

USGS
science for a changing world

Petromyzon marinus



Gnathostomes: Jawed Vertebrates

- Hinged jaws developed from the pharnygeal arches
- Evolution resulted in the modification of an existing feature to form the jaw
  - Some gill arches were lost, some modified

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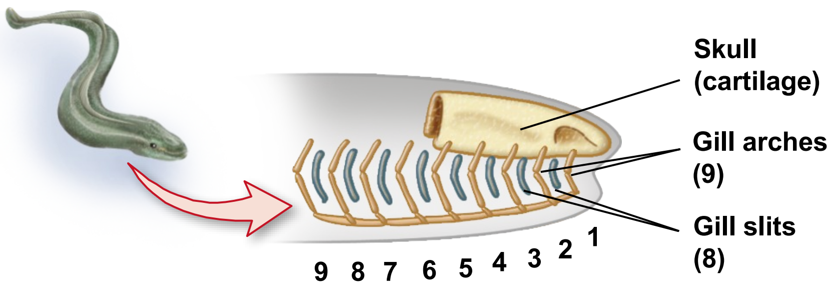
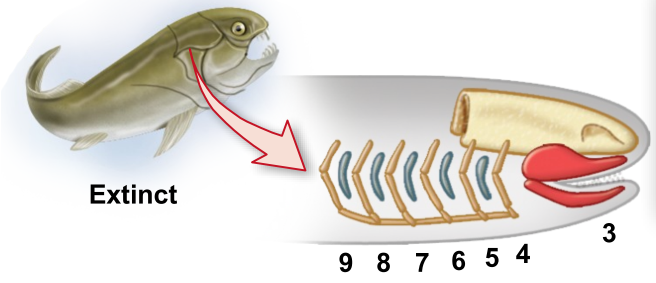
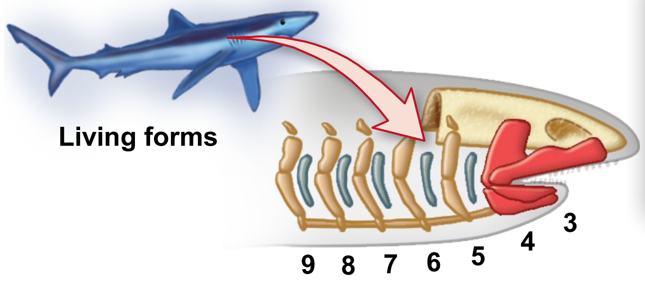


(a) Primitive jawless fishes



Gill arches 1 and 2 were lost; 3 became modified to form a hinged jaw.

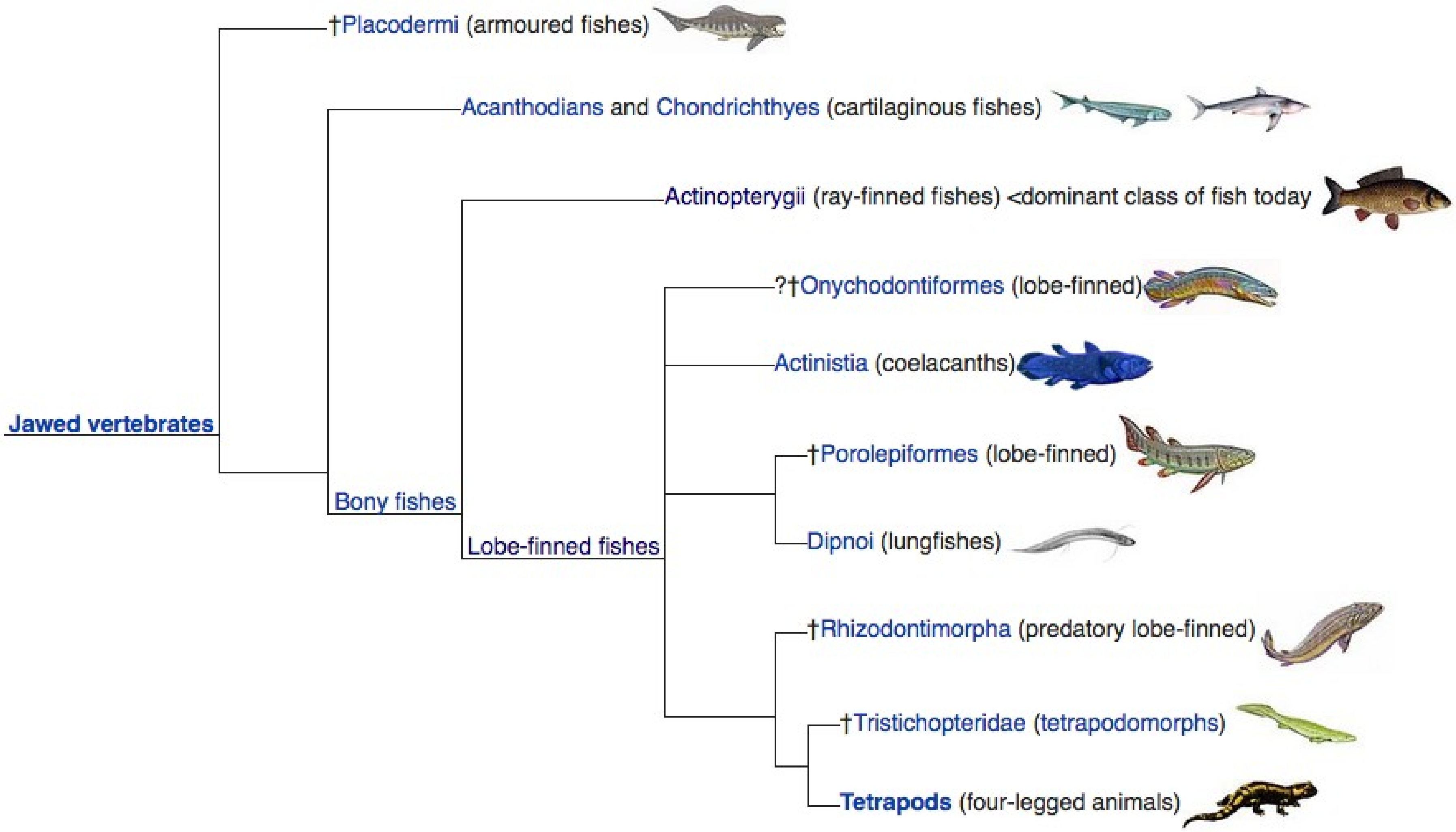
(b) Early jawed fishes (placoderms)



Gill arch 4 also became modified to form a heavier, more efficient jaw.

(c) Modern jawed fishes (cartilaginous and bony fishes)

Jawed vertebrate evolution


†Placodermi (armoured fishes)
Acanthodians and Chondrichthyes (cartilaginous fishes)
Actinopterygii (ray-finned fishes) <dominant class of fish today
?†Onychodontiformes (lobe-finned)
Actinistia (coelacanths)
†Porolepiformes (lobe-finned)
Dipnoi (lungfishes)
†Rhizodontimorpha (predatory lobe-finned)
†Tristichopteridae (tetrapodomorphs)
Tetrapods (four-legged animals)
Jawed vertebrates
Bony fishes
Lobe-finned fishes

ELASMOBRANCH (sharks and rays) CHARACTERISTICS- details

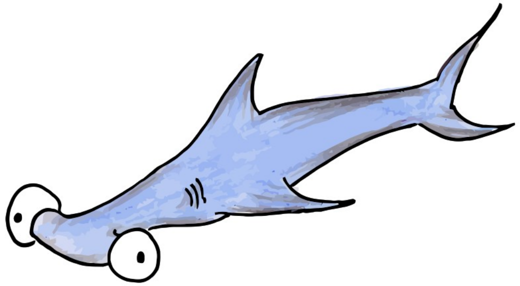
- **Fusiform (spindle-shaped, tapering at both ends) body, HETEROCERCAL (unequal lobes) CAUDAL (tail) fin**
- **Ventral mouth – upper jaw NOT attached to skull**
- **Paired solid PECTORAL and PELVIC fins**
- **PLACOID scales**
- **Endoskeleton entirely CARTILAGE**
- **Separate and exposed gill slits (5-7)**
- **No swim bladder**
- **Well developed senses of smell, vibration, and electroreception**
- **Internal fertilization**
- **2-chambered heart**

Chondrichthyes: Cartilaginous Fishes

Overview - Sharks, Skates, and Rays

- About 970 living species
- Well-developed sense organs, powerful jaws, and predaceous habits helped them survive.
- True bone (with minerals) is completely **absent** throughout the class (a derived character – a developmental change prevented ossification of cartilage.) Cartilage of skeleton is more flexible.
- Mineral tissues retained in teeth, scales, and spines.
- After whales, sharks are the largest living vertebrates, reaching 12 meters in length.

dreamstime.com



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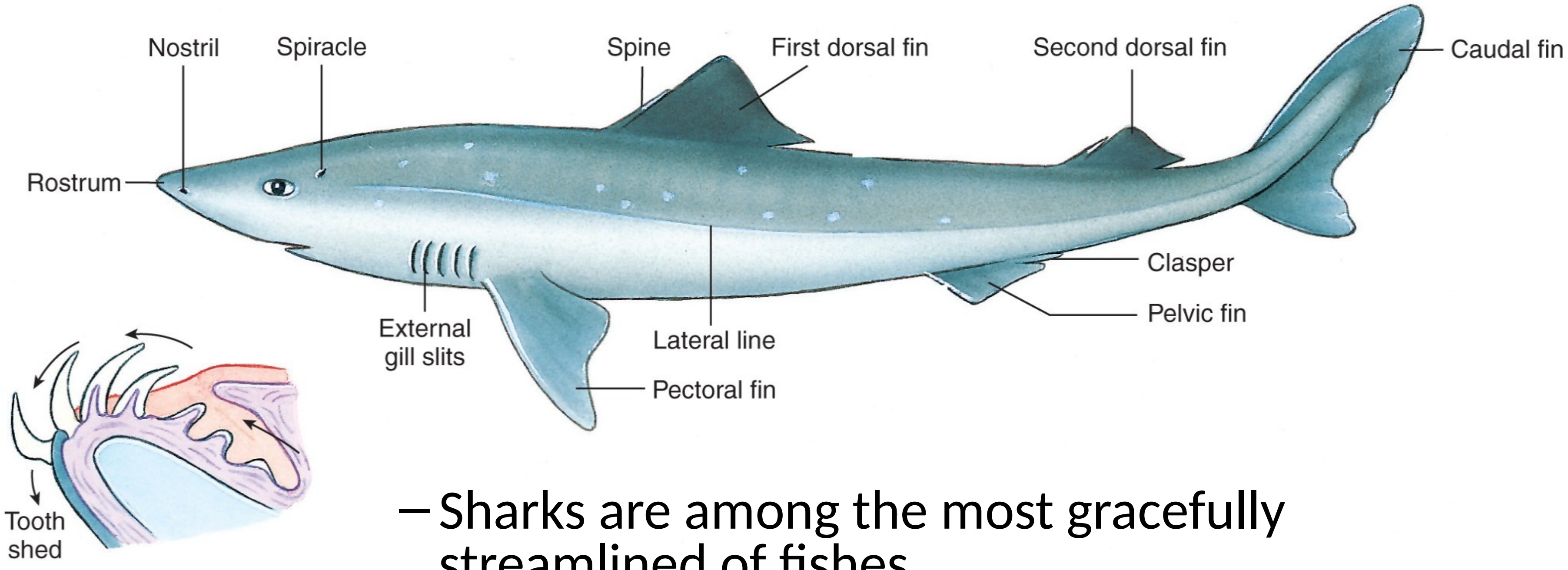


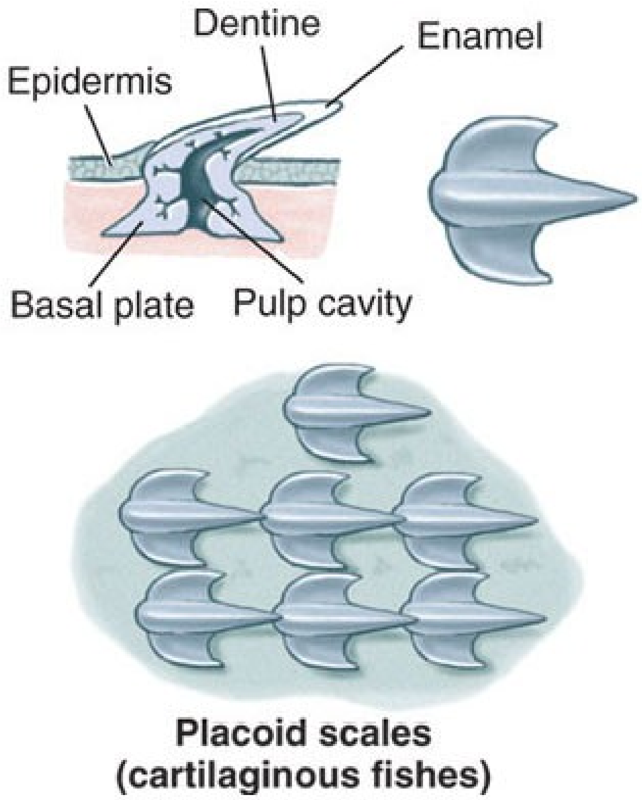
- Sharks are among the most gracefully streamlined of fishes

- Thrust and lift provided by an asymmetrical *heterocercal tail*

    - Vertebral column turns upward and extends into dorsal lobe of caudal fin

Chondrichthyes: Placoid scales

- Tough, leathery skin with *placoid scales* (structurally homologous to human teeth). Fish scales in general coded for by same genes for mammal tooth and hair
  - *Modified to form replaceable rows of teeth in both jaws*



Shark teeth

- Sharks are among the earliest fish to develop teeth.
- Sharks average out to 15 rows of teeth in each jaw. Although most have 5, and the bull shark that has 50 rows of teeth.
- Shark teeth are arranged in neat conveyor belt rows and can be replaced within a day of losing one.
- Shark teeth are not attached to gums on a root like our teeth.
- Sharks typically lose at least one tooth per week.
- The inside of shark and human teeth contains a soft mineral known as dentin.

SHARK
ACADEMY

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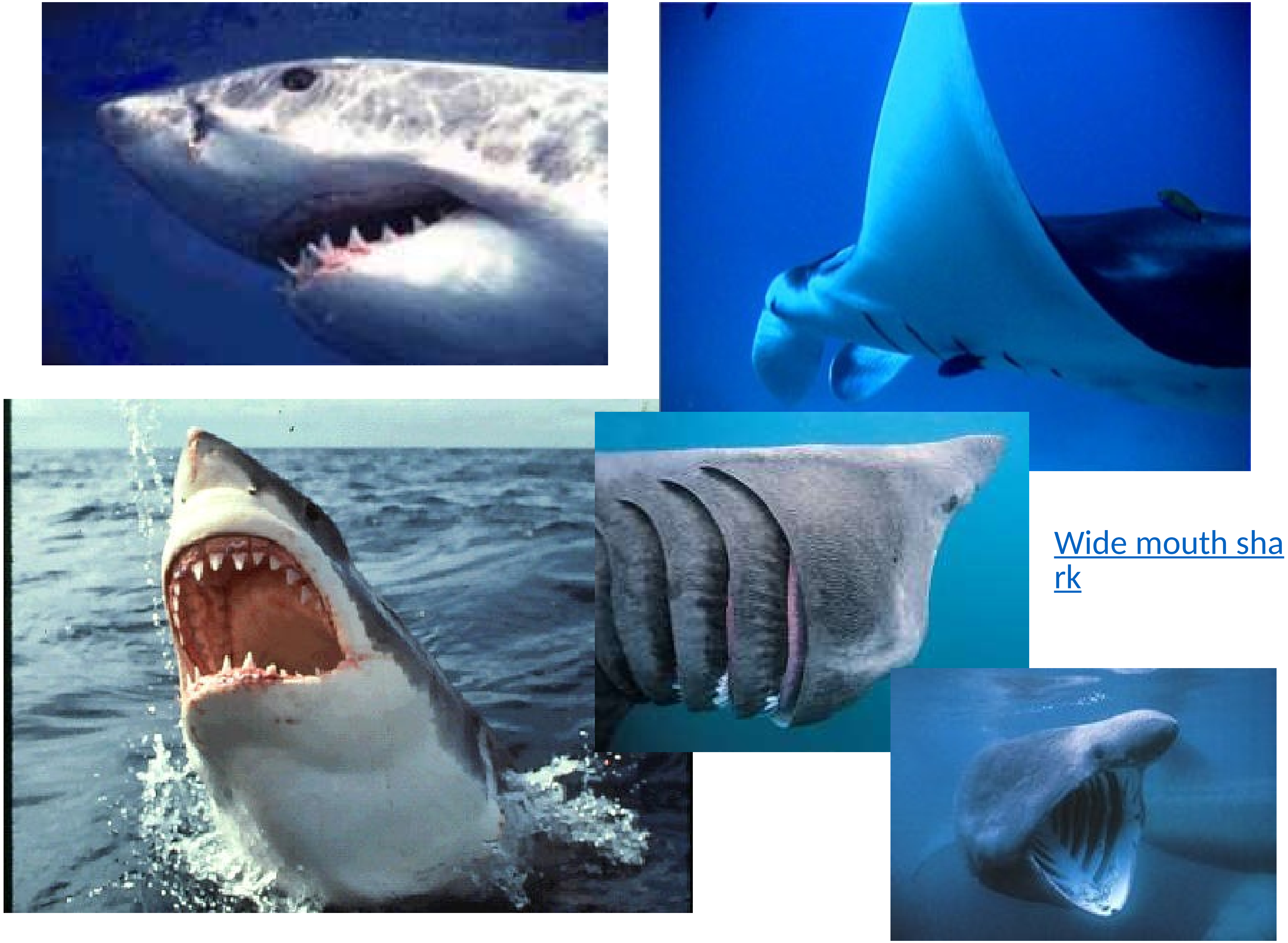
© IFA-Bilderteam/Getty Images



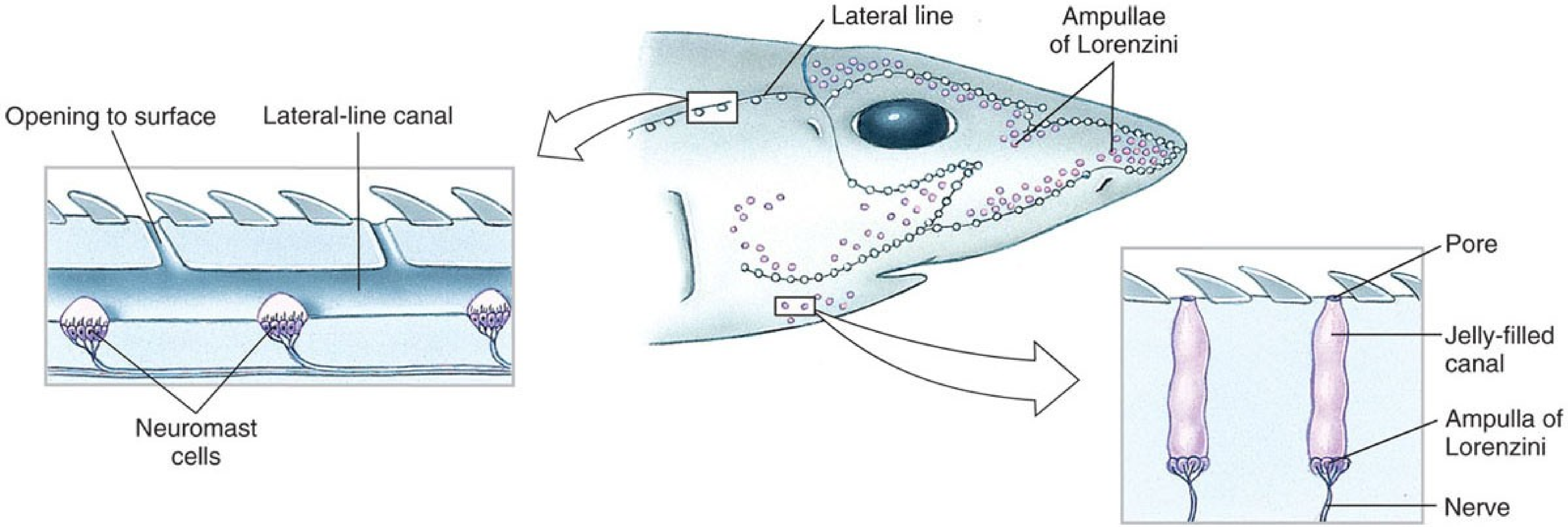
Wide mouth shark

Chondrichthyes: Senses

- Prey can also be located from long distances sensing low frequency vibrations in the *lateral line*
  - Consists of *nerves in interconnected tubes and pores on side of body*
  - *At close range,* switch to vision

Chondrichthyes: Sense organs

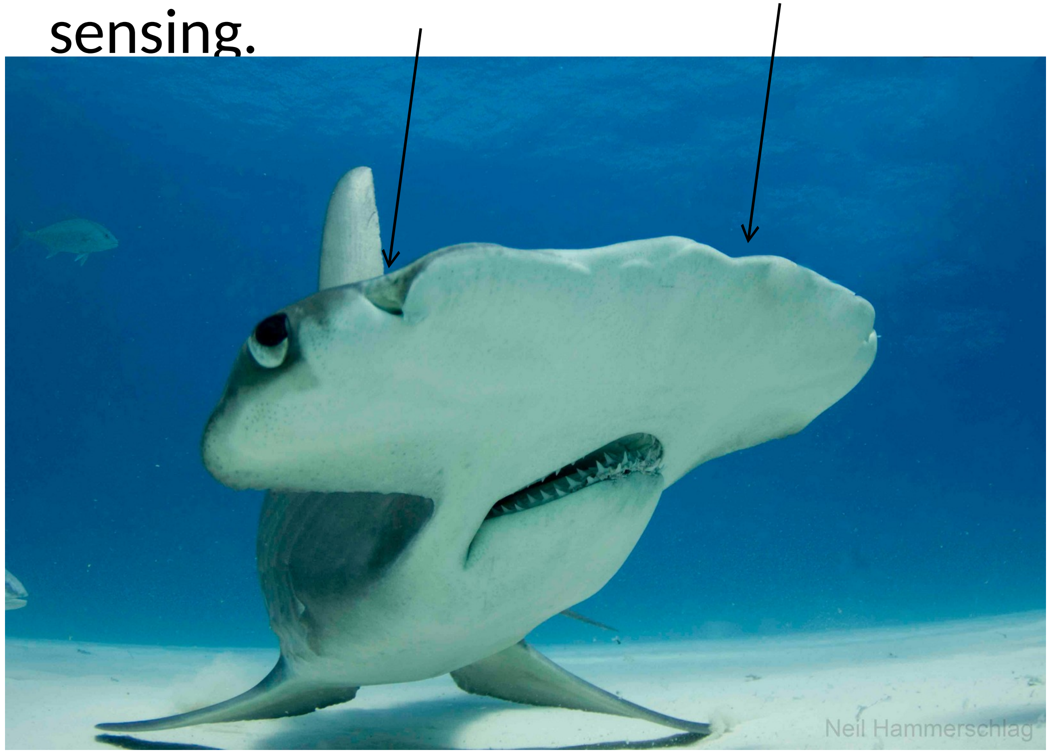
- Electoreceptors
  - Up close, sharks are guided by *bioelectric fields* that surround all animals
  - Electroreceptors, *the ampullae of Lorenzini,* are located on the shark's head

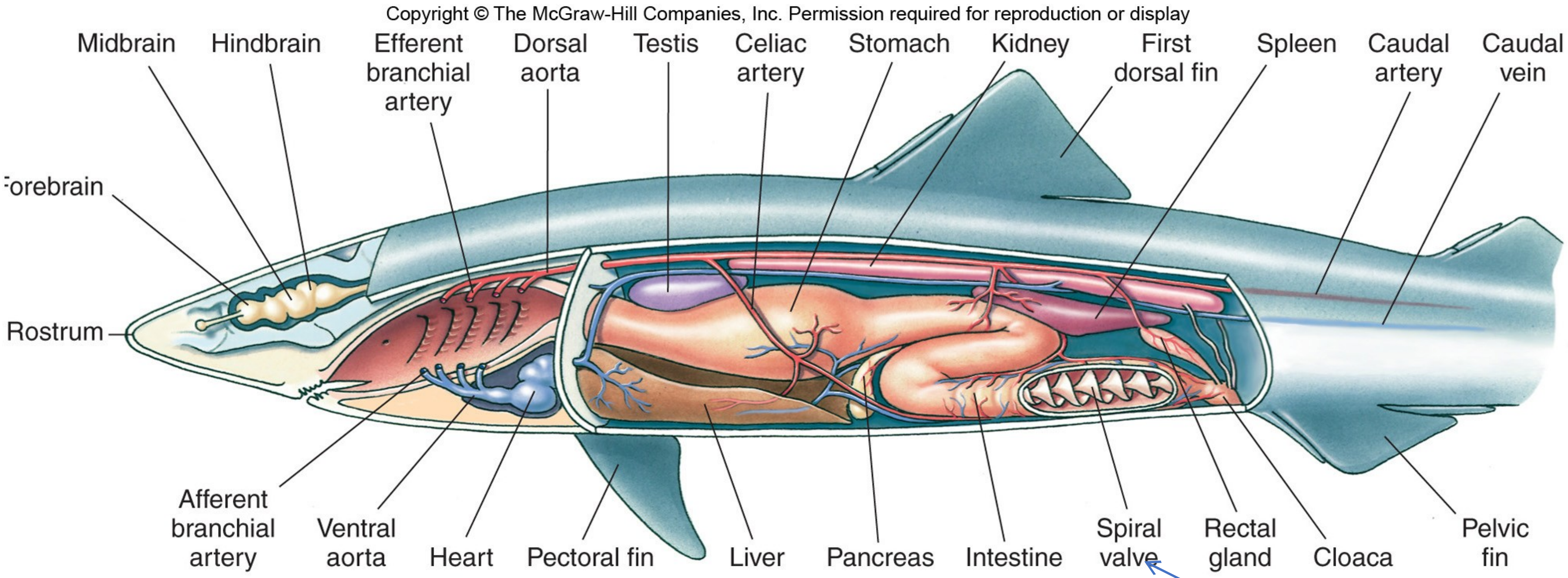


Olfaction in sharks

- Olfactory chemical sensors
  - Detect prey at a distance by large olfactory organs sensitive to *one part per 10 billion of blood in seawater*
  - Use timing between signals at each nostril to figure out direction of prey
  - Also attracted to chemicals in prey intestines, and may accidentally hang out in areas where sewage dumps into the ocean.

- Hammerhead shows nostrils far apart, with farther range of olfactory sensing.


Neil Hammerschlag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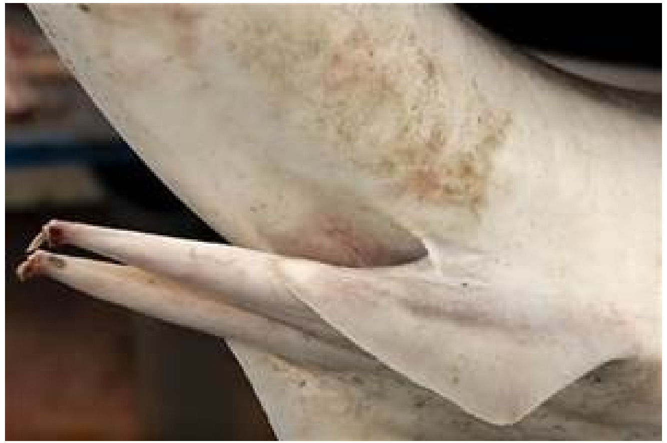
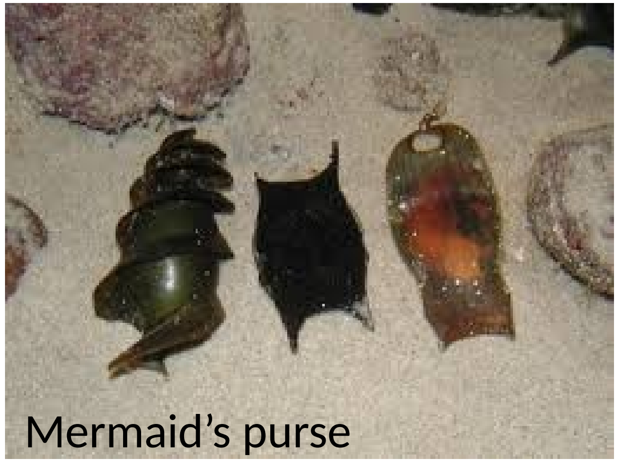
Increases surface area in intestine

Chondrichthyes: Reproduction

- In males, the medial part of the pelvic fin is modified to form a *clasper* used in copulation
- Fertilization is *internal*
- Maternal support of embryo is variable
  - Includes *oviparous, ovoviviparous, and viviparous species*
    - Oviparous – lay eggs
    - Ovoviparous – egg retained in female, no placenta
    - Viviparous – eggs develop in uterus, placenta nourishes young





Mermaid's purse

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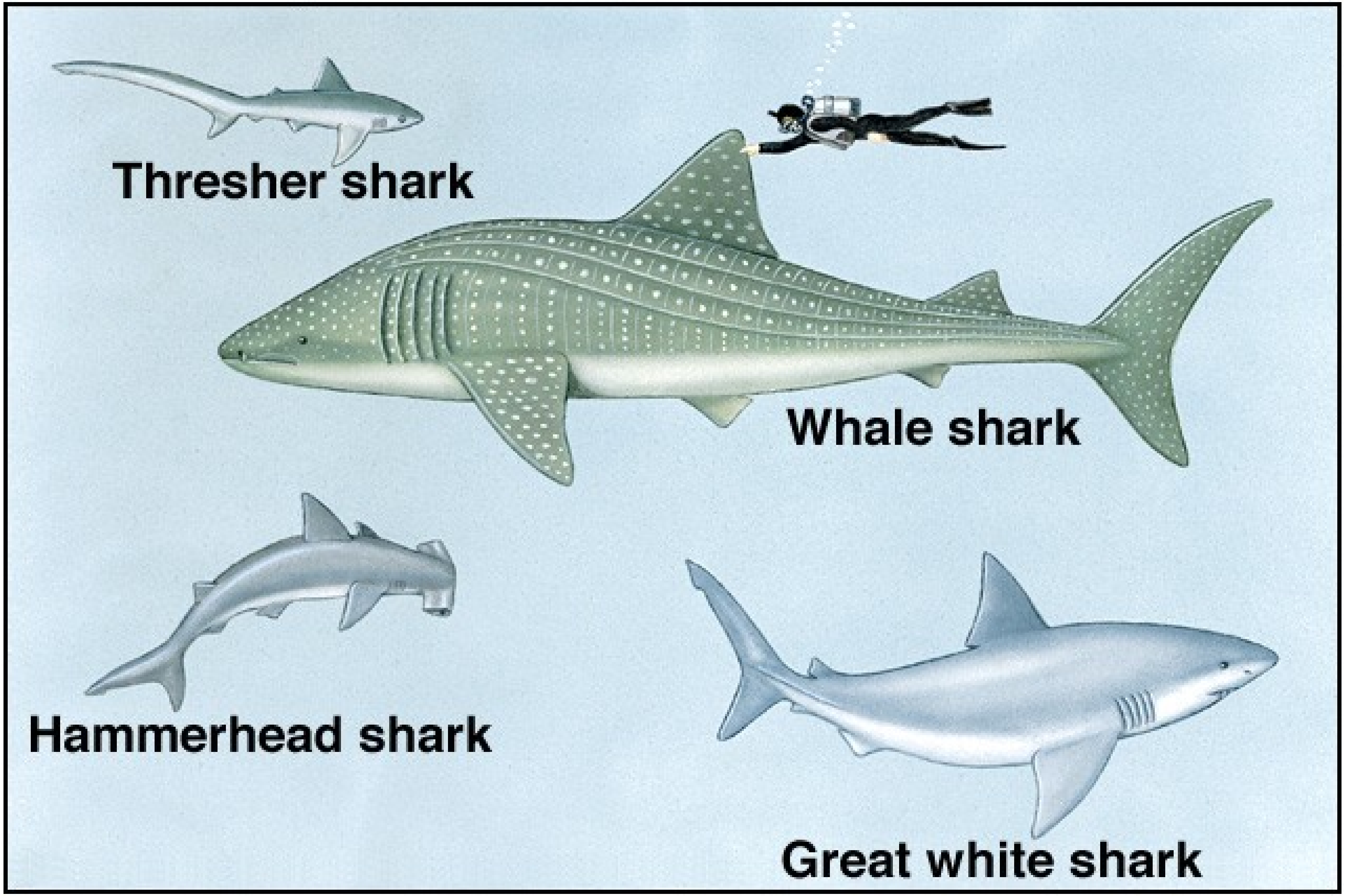
Diversity of Elasmobranchian sharks



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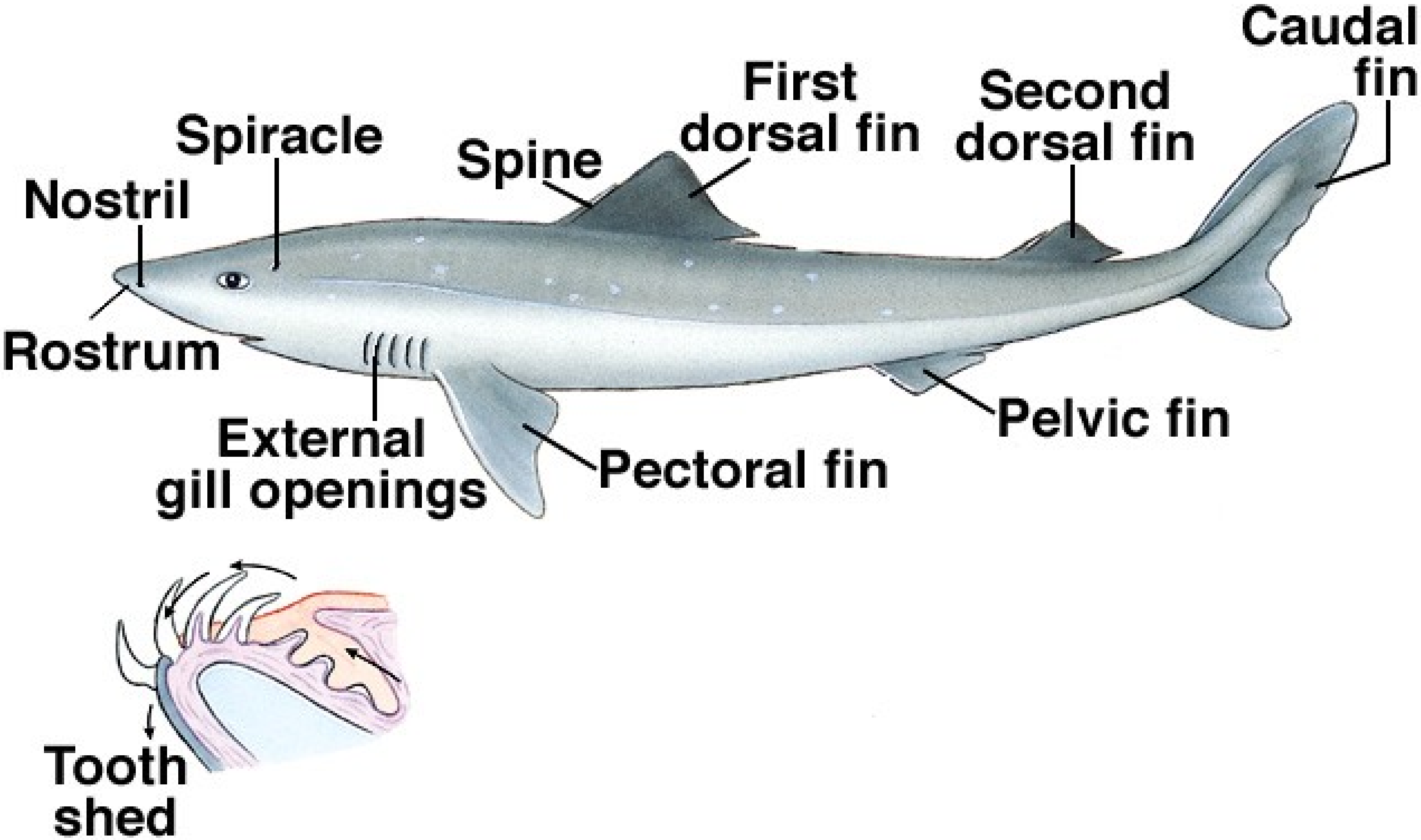
The dogfish shark *(Squalus)*

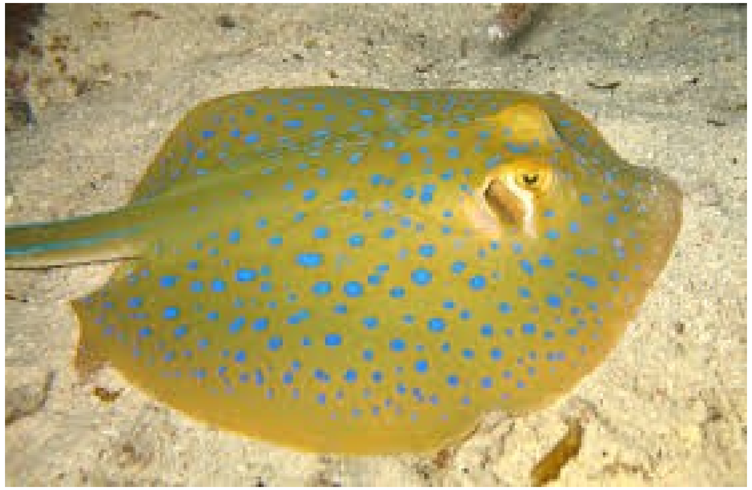


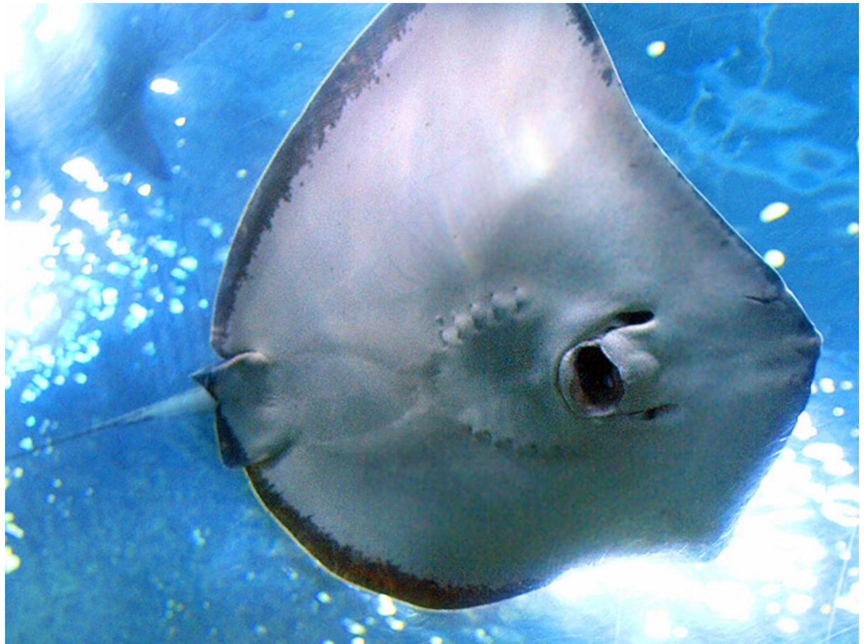
Shark breathing

- Gills and spiracles
- Breathing video

Chondrichthyes: Cartilaginous Fishes

- *Form and Function of Rays*
  - More than half of Chondrichthyes are *rays*
  - Dorsoventrally flattened body and enlarged pectoral fins used to propel themselves
  - Respiratory water enters through large spiracles on top of the head, gill openings are on underside of head





- Teeth adapted for *crushing prey*
  - Molluscs, crustaceans, and sometimes small fish
- *Stingrays*
  - Have whiplike tail with spines and venom glands
- *Electric rays*
  - Have large electric organs on each side of head

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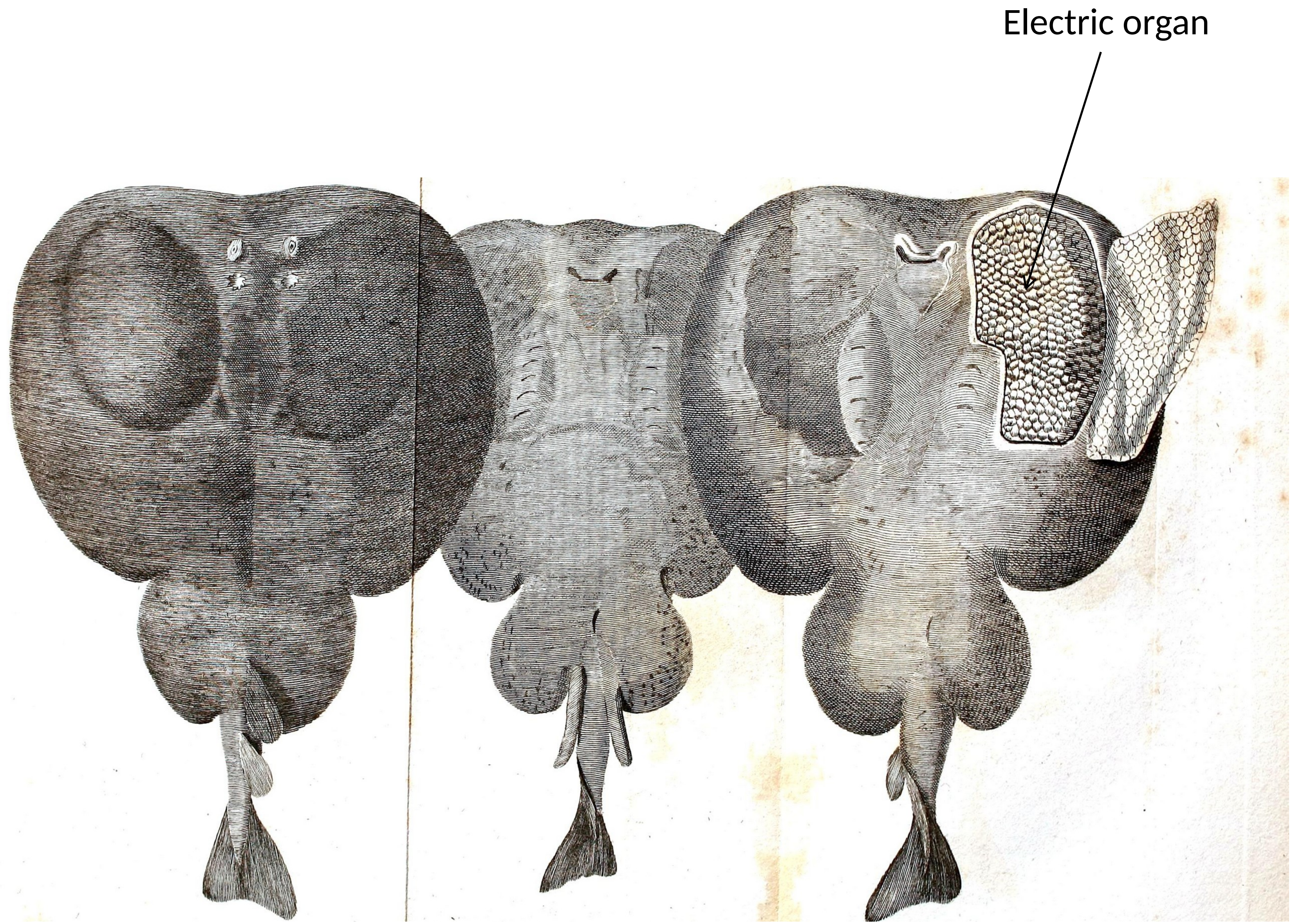
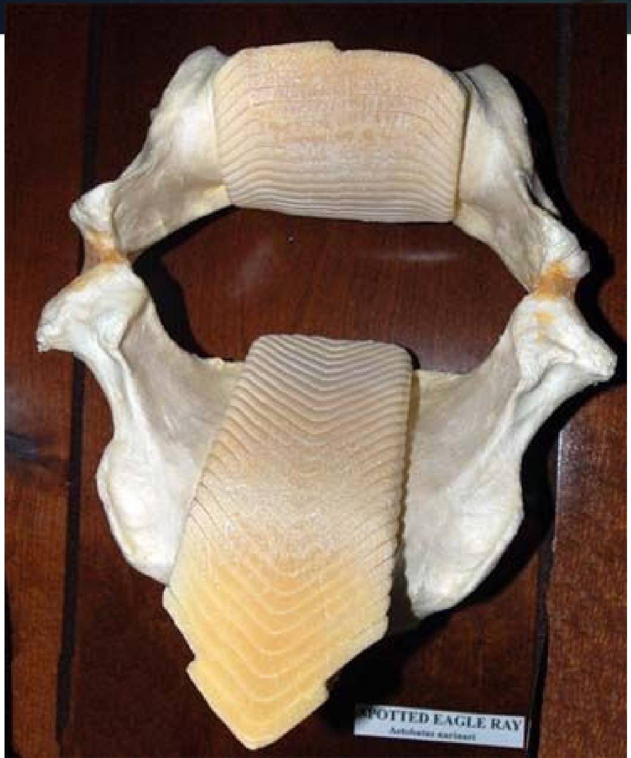
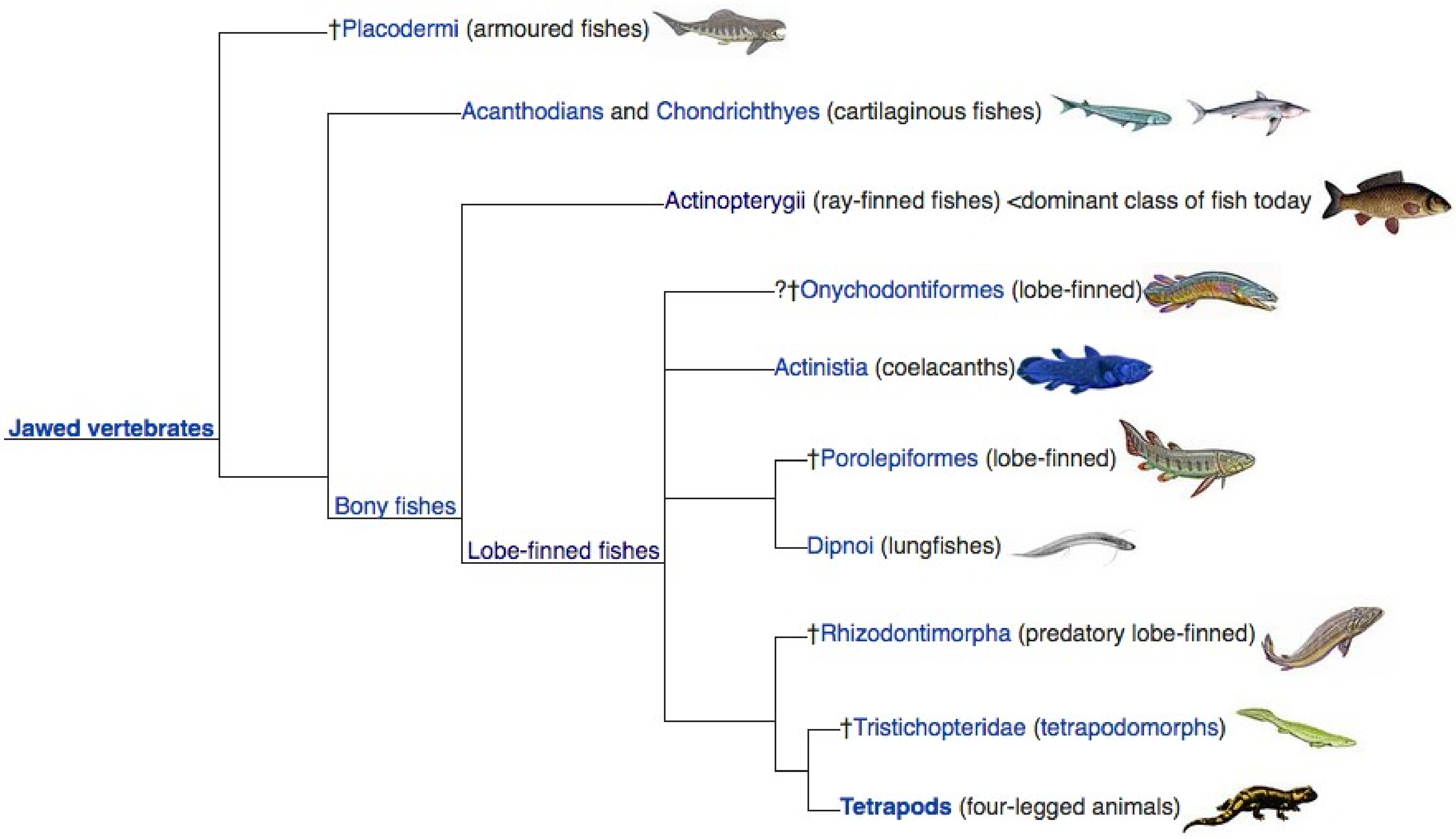

Electric organ


POTTED EAGLE RAY

Bony fish - Osteichthyes

- Three living classes or subclasses
- **Actinopterygii** – ray-finned fish
- **Sarcopterygii**
  - **Actinistia** – coelacanths
  - **Dipnoi** – lungfish
  - Note – the coelacanths and the lungfish are often grouped together in the Sarcopterygii

Jawed vertebrate evolution


†Placodermi (armoured fishes)
Acanthodians and Chondrichthyes (cartilaginous fishes)
Actinopterygii (ray-finned fishes) <dominant class of fish today
?†Onychodontiformes (lobe-finned)
Actinistia (coelacanths)
†Porolepiformes (lobe-finned)
Dipnoi (lungfishes)
†Rhizodontimorpha (predatory lobe-finned)
†Tristichopteridae (tetrapodomorphs)
Tetrapods (four-legged animals)
Jawed vertebrates
Bony fishes
Lobe-finned fishes

Bony fish > 25,000 species

CHARACTERISTICS

- **Bony skeleton, numerous vertebrae, HOMOCERCAL (equal lobes) tail**
- **Mucous glands in the skin, embedded dermal scales**
- **FIN RAYS of cartilage or bone**
- **Terminal anterior mouth**
- **OPERCULUM covers the gills**
- **SWIM BLADDER**
- **Fertilization usually external**

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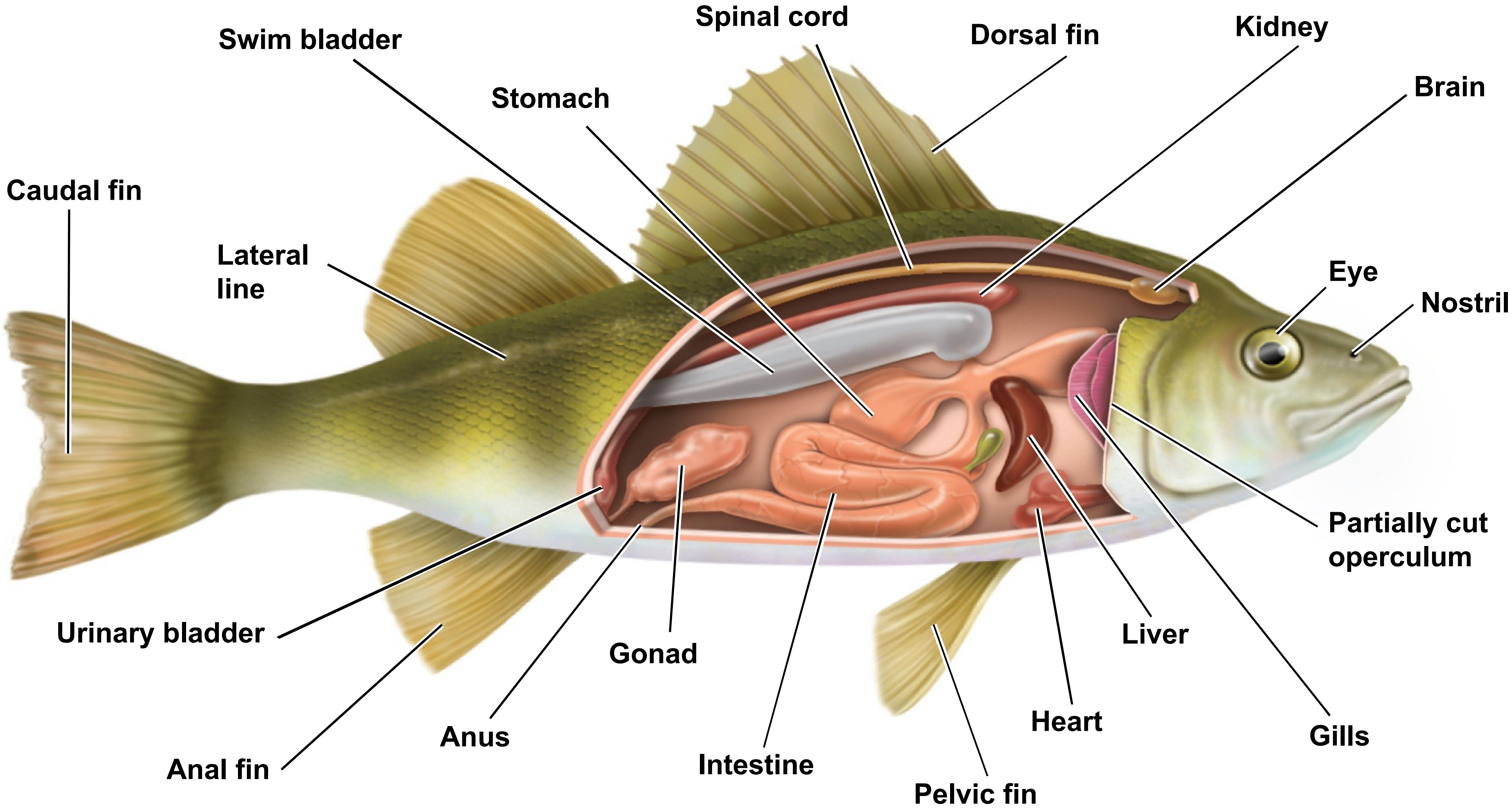

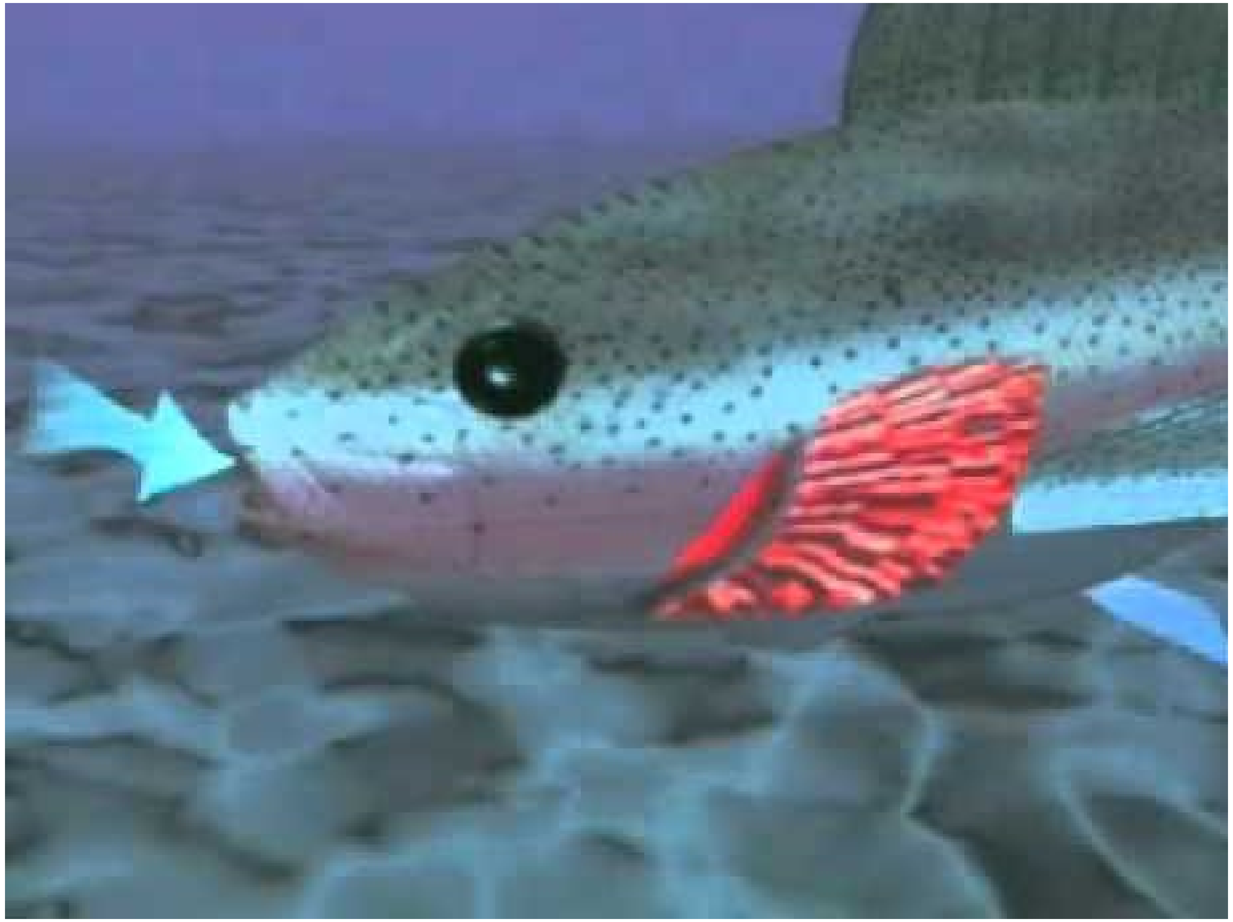

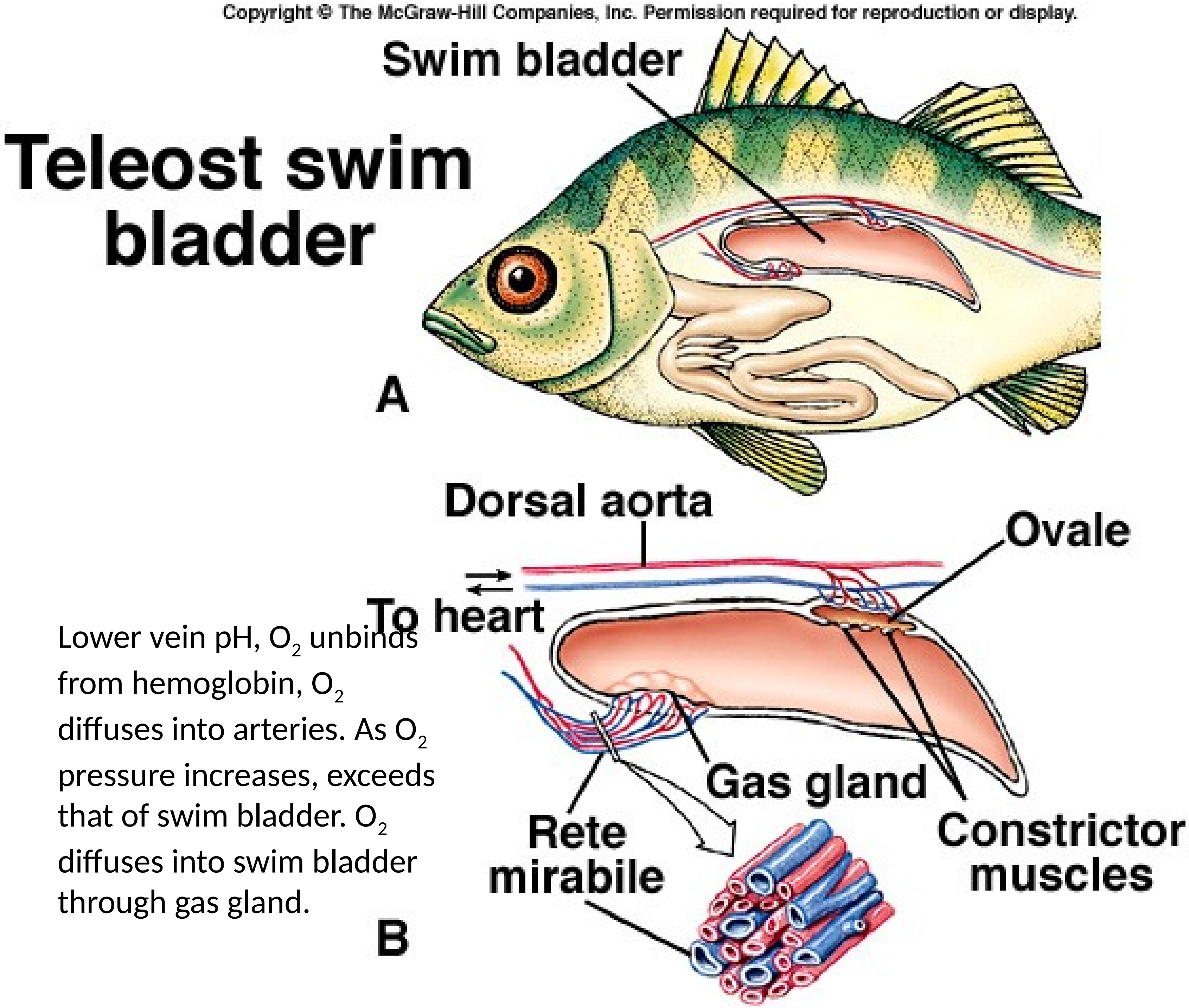
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Lower vein pH, O_2 unbinds from hemoglobin, O_2 diffuses into arteries. As O_2 pressure increases, exceeds that of swim bladder. O_2 diffuses into swim bladder through gas gland.

(c) Randy Morse
GoldenStateImages.com

Anchovies, photo courtesy of NOAA

- **Actinopterygii** – ray-finned fish
  - Includes all bony fish except coelacanths and lungfish
  - Fins supported by thin, bony, flexible rays

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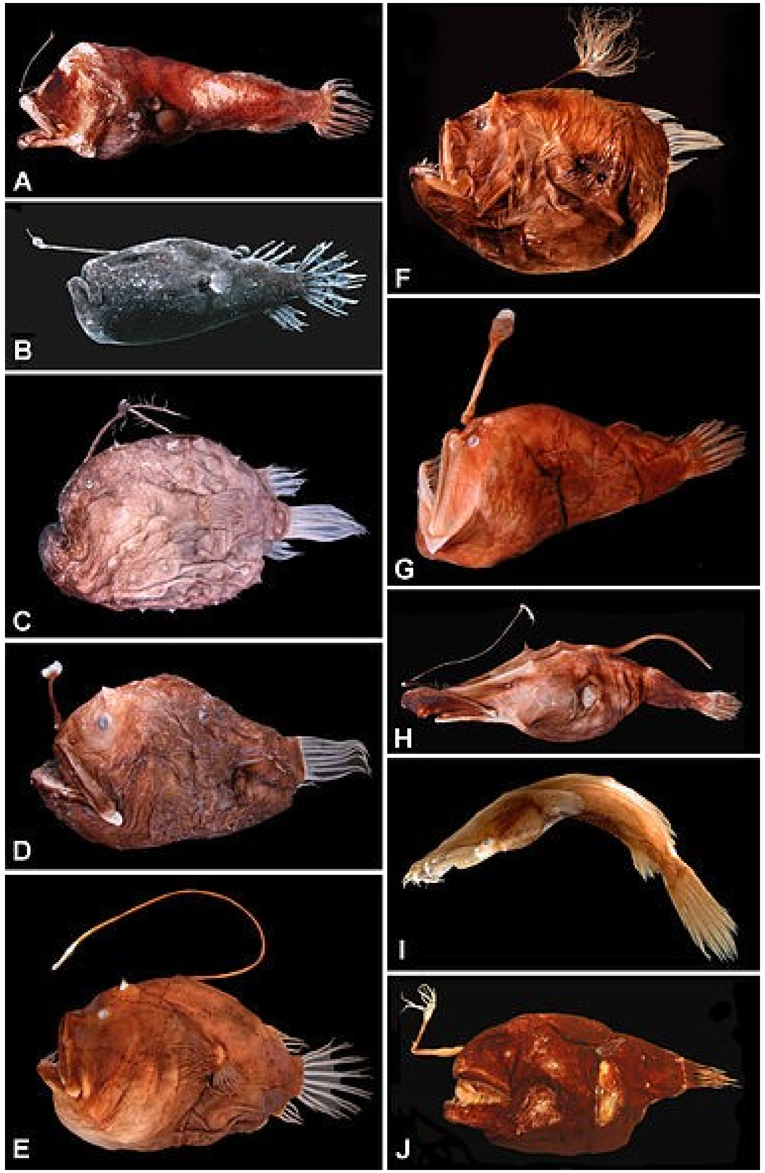
(a) Lionfish (*Pterois volitans*)

(b) Whitemouth moray eel (*Gymnothorax meleagris*)

(c) Leafy sea dragon (*Phycodurus eques*)

a: © Reinhard Dirscherl/Visuals Unlimited; b: © Andrew Dawson/agefotostock; c: © Luc Novovitch/Getty Images

Anglerfish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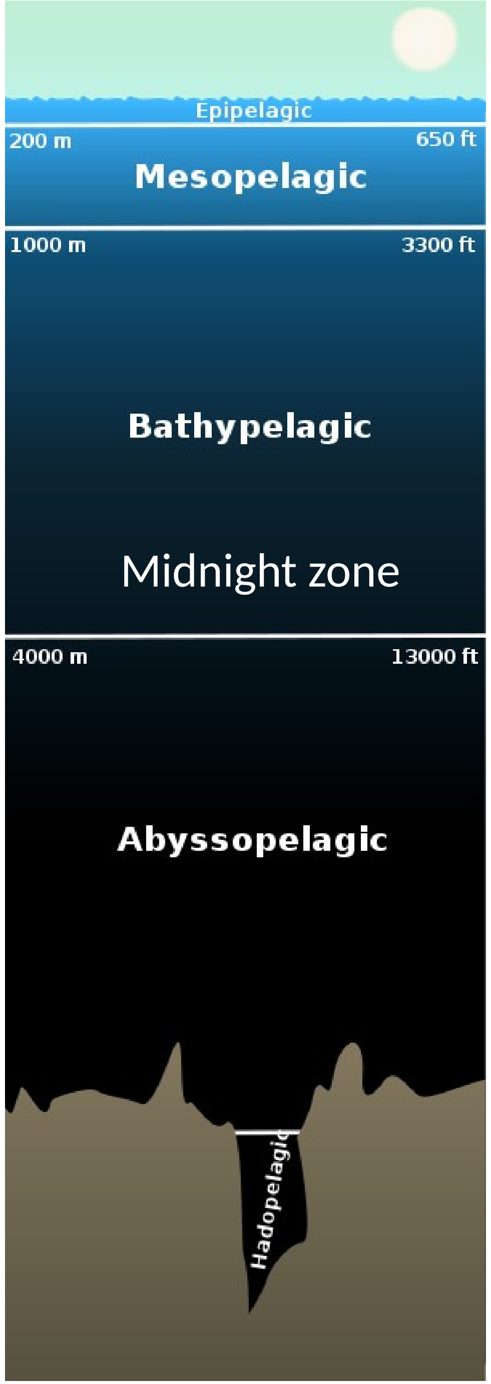
Epipelagic
200 m
650 ft
Mesopelagic
1000 m
3300 ft
Bathypelagic
Midnight zone
4000 m
13000 ft
Abyssopelagic
Hadopelagic

When a male finds a female, he bites into her skin, and releases an enzyme that digests the skin of his mouth and her body, fusing the pair down to the blood-vessel level.[14]

The male becomes dependent on the female host for survival by receiving nutrients via their shared circulatory system, and provides sperm to the female in return. After fusing, males increase in volume and become much larger relative to free-living males of the species. They live and remain reproductively functional as long as the female lives, and can take part in multiple spawnings.[2] This extreme sexual dimorphism ensures that when the female is ready to spawn, she has a mate immediately available.[15]

Multiple males can be incorporated into a single individual female with up to eight males in some species, though some taxa appear to have a "one male per female" rule.[2] https://en.wikipedia.org/wiki/Anglerfish

- **Actinistia** – coelacanths (lobe finned fish)
  - Believed extinct until 1938. Deep-water fish
  - Special intracranial joint in skull gives powerful bite
  - Notochord remains and is oil-filled
  - Swim bladder filled with oil rather than gas – still used for buoyancy – so is braincase…98.5%

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NAT GEO
WILD

- **Dipnoi** – lungfish (lobe finned fish)
  - 3 genera with 6 species
  - Live in oxygen-poor freshwater
  - Both gills and lungs – can drown if unable to breathe air
  - Muscular lobe fins allow them to traverse land when lake dries out

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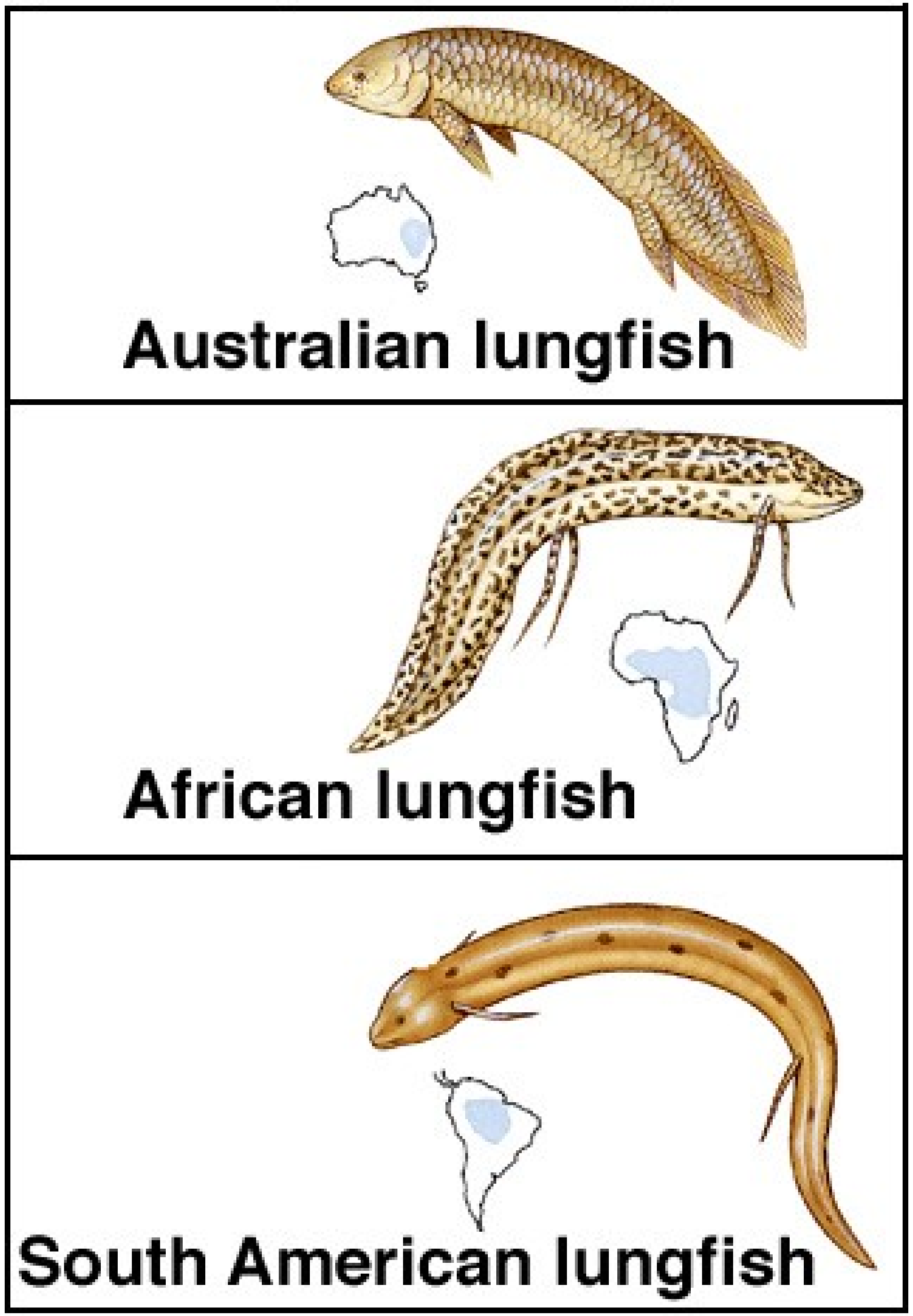
Lungfishes

Sarcopterygii

Link to video above – click on picture



Lungfishes

Sarcopterygii

Link to video above – click on picture

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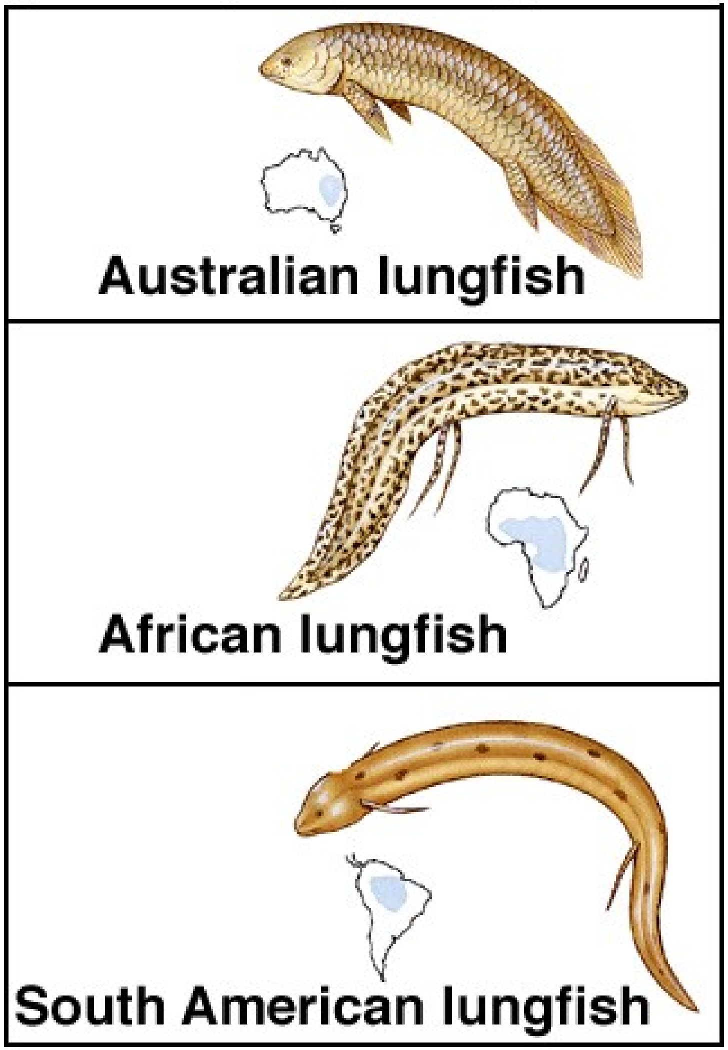

Tetrapods: Gnathostomes with Four Limbs

Transition to land involved adaptations for locomotion, reproduction, and to prevent desiccation

Sturdy lobe-finned fishes led to the evolution of animals with four limbs

Vertebral column strengthened, hip and shoulder bones braced against backbone

Relatively simple changes in gene expression, especially **Hox genes**

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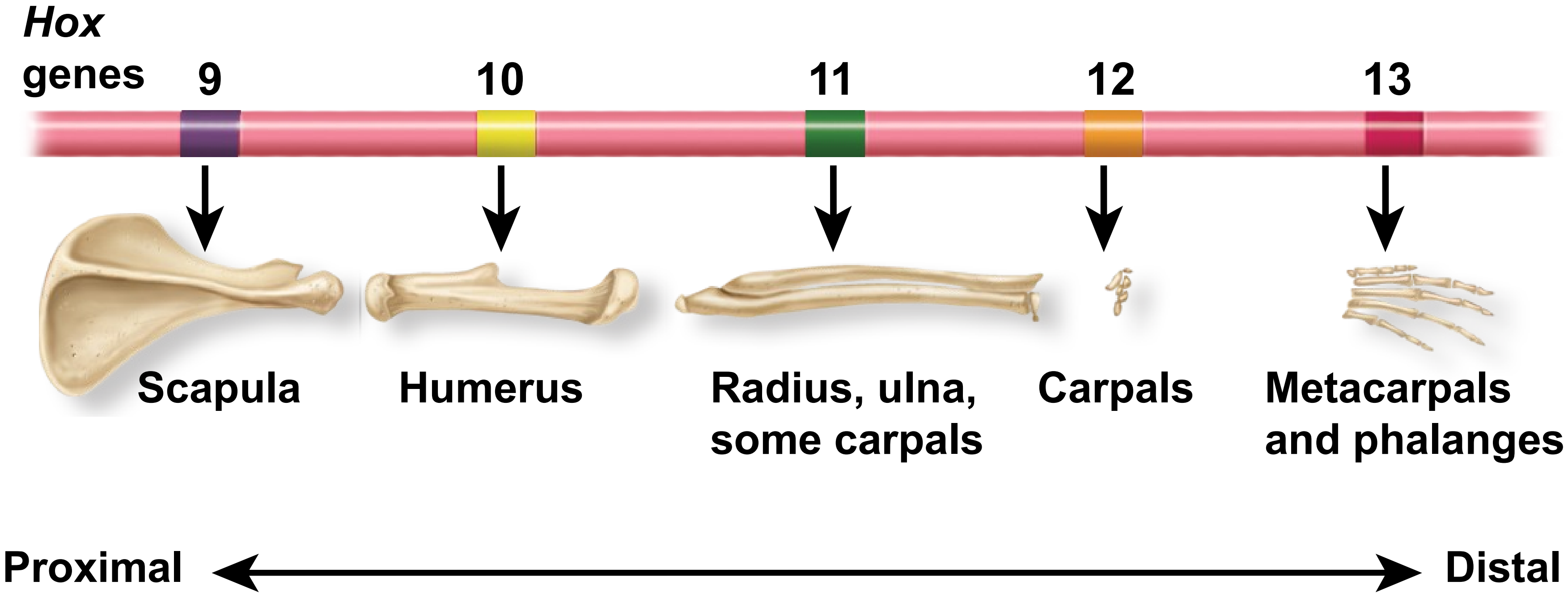

***Hox* genes**

9

10

11

12

13

Scapula

Humerus

Radius, ulna, some carpals

Carpals

Metacarpals and phalanges

Proximal

Distal

***Hox* genes 9–13** work together to specify limb formation from proximal to distal (from the point of attachment to the body to the end of the limb)

Transitional taxa

E.g. *Tiktaalik rosae,* or the **Fishapod** (discovered 2004)

Fishapods had broad skulls, eyes on top, lungs, pectoral fins with 5 finger-like bones

Species increasingly fed on land but was still tied to water for reproduction

320mya *Cacops* was similar to modern amphibians

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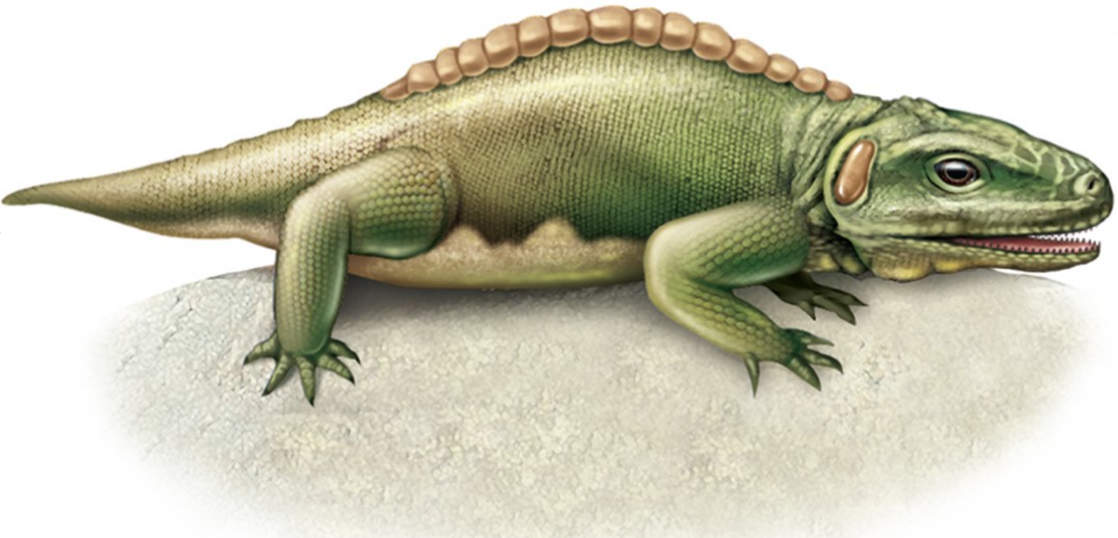

DAVIS AND COLLEAGUES PROVIDE A GENETIC-DEVELOPMENTAL EXPLANATION FOR LIMB LENGTH IN TETRAPODS

Specific *Hox* genes are responsible for determining limb formation in mice

Experimental mutations in the genes *HoxA-11* and *HoxD-11* resulted in the loss of the radius, ulna, and some of the carpals

Relatively simple mutations can control relatively large changes in limb development

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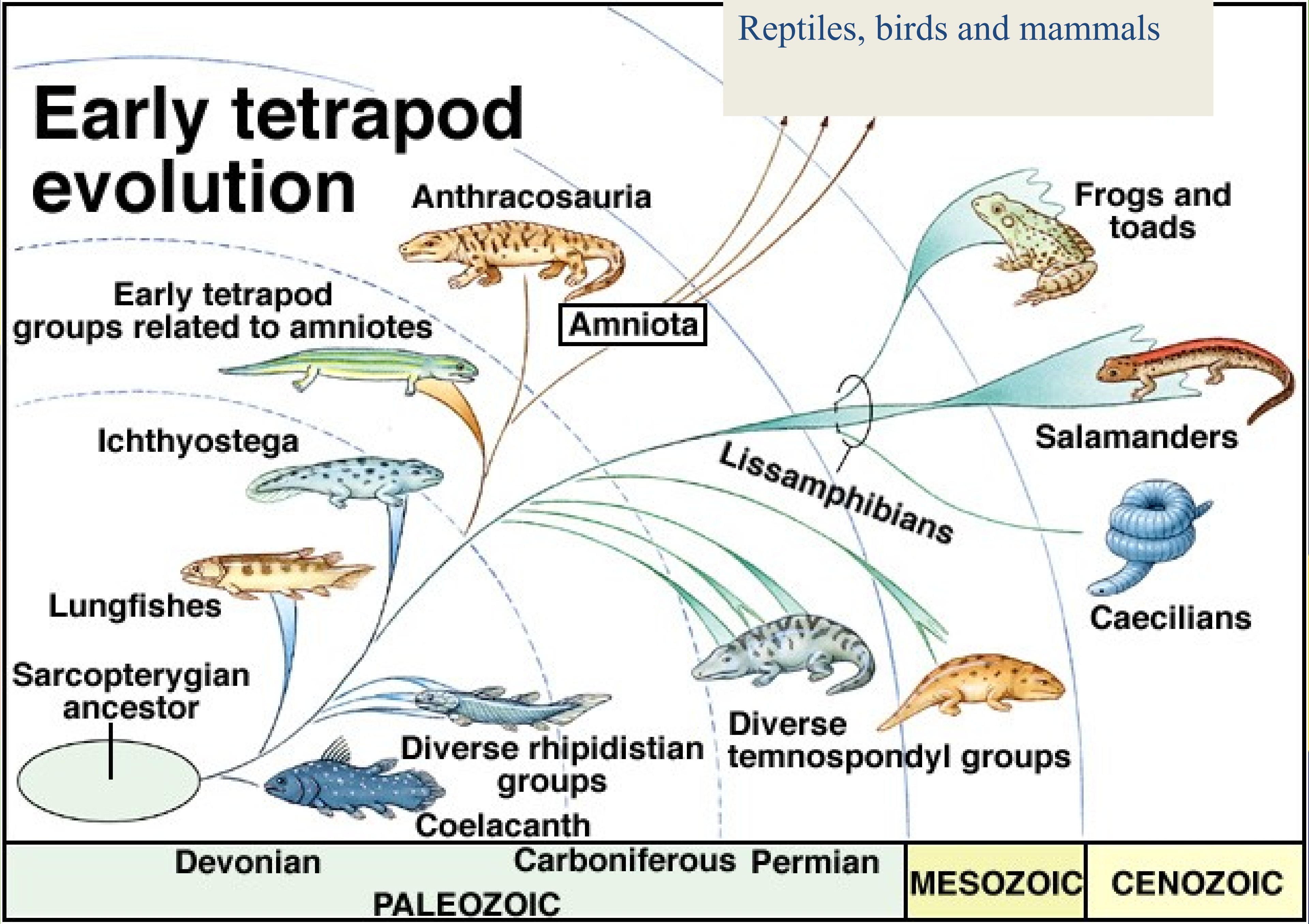
Reptiles, birds and mammals



CRANIATA – CLASS AMPHIBIA – THE AMPHIBIANS

Amphibians are the first of the TETRAPOD (four limbs) taxa. The tetrapods (amphibians, reptiles, birds, and mammals) form a monophyletic group. There are ~ 4,000 living species of amphibian.

AMPHIBIANS

Successfully invaded land but must return to water to reproduce

Buccal (mouth) pumping to force air into lungs, with additional respiration through thin, moist skin, and gills in larval forms.

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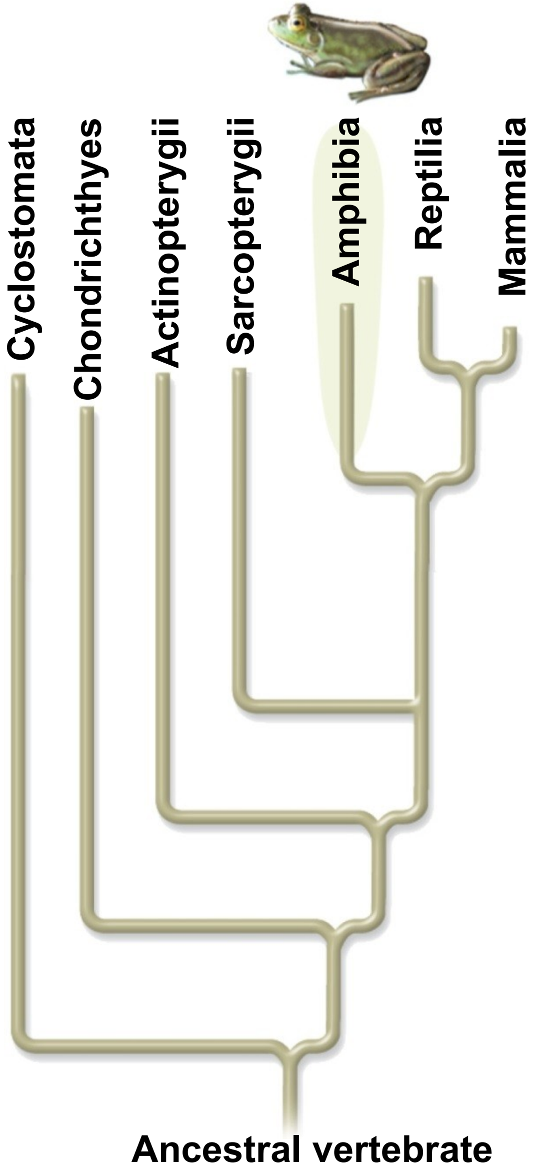

MOVEMENT ONTO LAND

Physical differences that must be addressed when moving from water to land?

MOVEMENT ONTO LAND

Physical differences that must be addressed when moving from water to land

- *Air is 1000 times less dense*
  - Provides less buoyancy than water

MOVEMENT ONTO LAND

Physical differences that must be addressed when moving from water to land

- *Air is 1000 times less dense*
  - Provides less buoyancy than water
  - Limbs and skeleton must support more weight

MOVEMENT ONTO LAND

Physical differences that must be addressed when moving from water to land

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  - Limbs and skeleton must support more weight
- *Air changes temperature more rapidly than water*

MOVEMENT ONTO LAND

Physical differences that must be addressed when moving from water to land

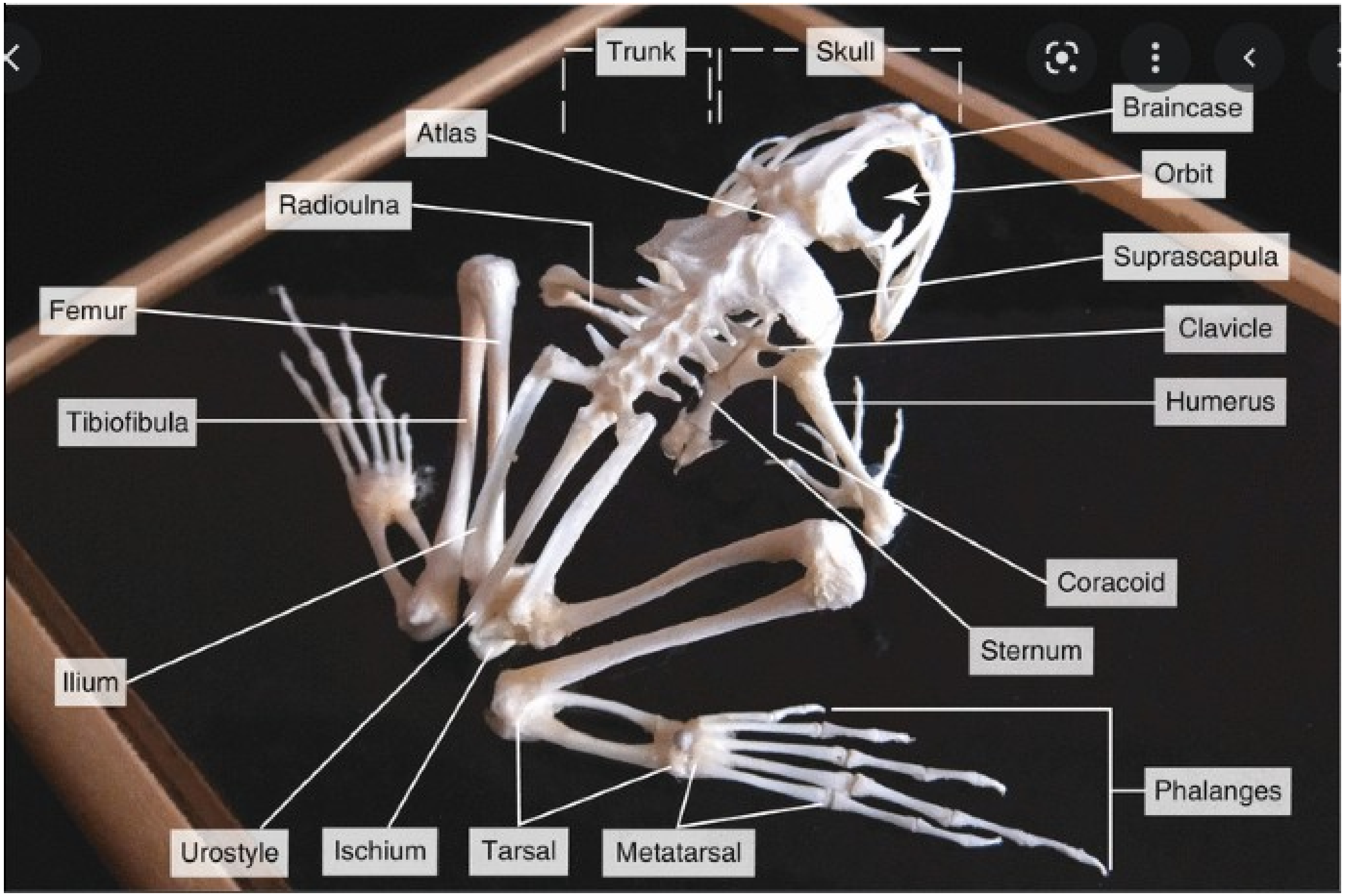
- *Air is 1000 times less dense*
  - Provides less buoyancy than water
  - Limbs and skeleton must support more weight
- *Air changes temperature more rapidly than water*
  - Animals must adjust to these extremes

EARLY EVOLUTION OF TERRESTRIAL VERTEBRATES

Tetrapods

- Have stronger backbone
- Muscles to support the body in air
- Muscles to elevate the head
- Stronger shoulder and hip girdles
- More protective rib cage
- Modified ear structure to detect airborne sounds

FROG SKELETON



Lőw, P., Molnár, K., Kriska, G. (2016). Dissection of a Frog (*Rana* sp.). In: Atlas of Animal Anatomy and Histology. Springer, Cham. https://doi.org/10.1007/978-3-319-25172-1_10

AMPHIBIAN CHARACTERISTICS

- Entirely freshwater or terrestrial
- Bony skeleton, variable numbers of vertebrae, ribs present or absent
- Wide variety of body forms
- Usually four limbs
- Smooth, moist skin with glands: no scales
- Large, toothed mouth: paired nostrils opening into anterior part of mouth
- Lungs, gills, or skin used for gaseous exchange
- Circulatory system with THREE-CHAMBERED heart, double circulation: a SYSTEMIC circulation to the body, and a PULMONARY circulation to the lungs
- Dioecious, fertilization internal or external, OVIPAROUS or OVOVIVIPAROUS
- Eggs are moderately yolky, with jelly like covering

MODERN AMPHIBIANS

- Thin skin loses water rapidly
  - Restricts them to moist habitats
- *Ectotherms*
  - Body temperature depends on environment and *restricts range*
- Eggs easily dessicate and must be shed into water or kept moist

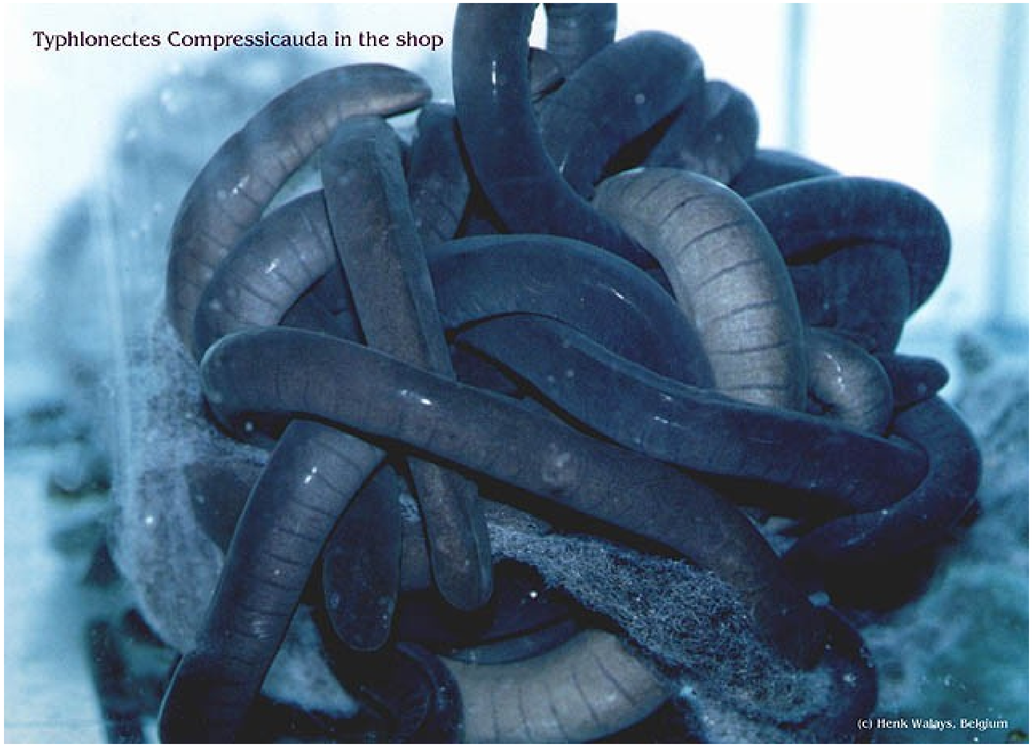
MODERN AMPHIBIANS

Respiration

- Wide array of respiratory mechanisms
- Use skin for respiration
- At various stages, may also have external gills, lungs, both gills and lungs, or neither
- Salamanders with aquatic stage hatch with gills which are lost at metamorphosis
- Several species fail to undergo metamorphosis and retain gills and a fin-like tail

ORDER GYMNOPHIONA (APODA) – CAECILIANS

- 160 species.
- Elongate, limbless, burrowing creatures found in tropical forests and streams. (Central and South America, Africa, south Asia.)



Typhlonectes Compressicauda in the shop

(c) Henk Walays, Belgium

CAECILIANS

Caecilians: Order Gymnophiona

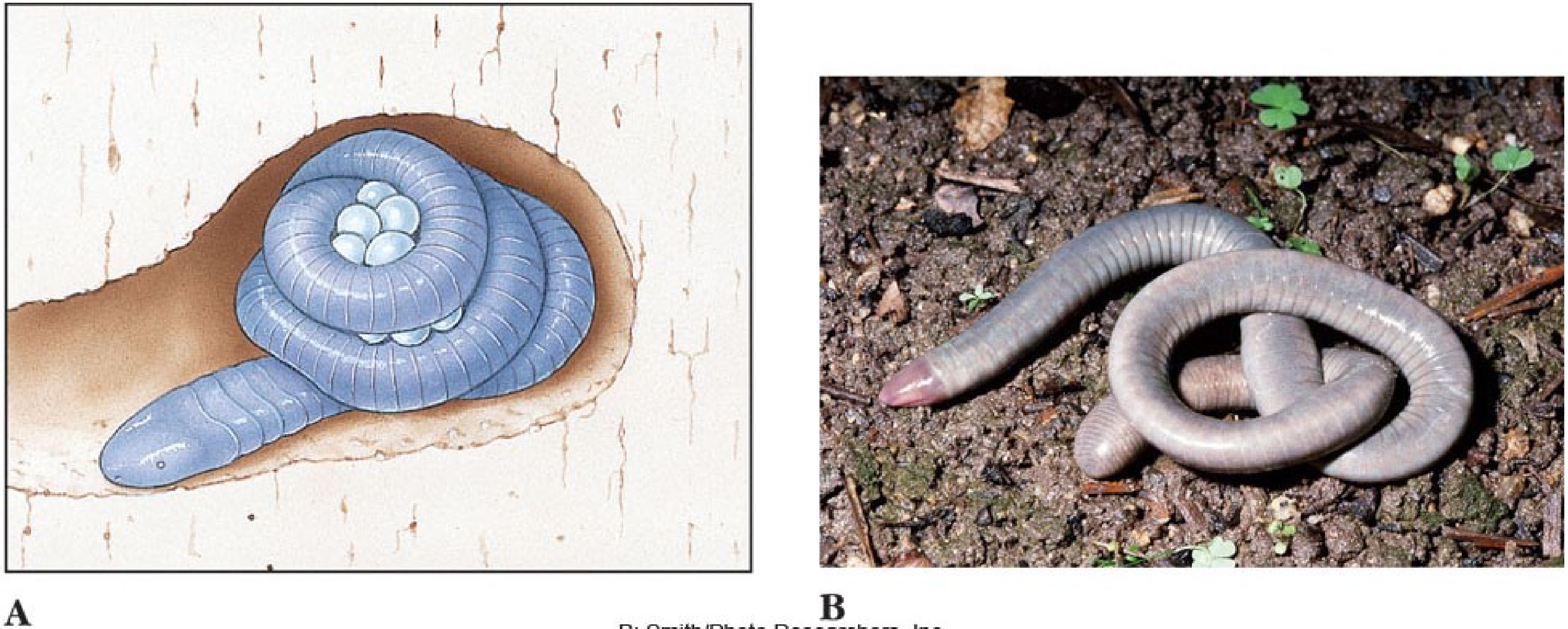
Elongate, limbless, burrowing animals (look like snakes)

Inhabit tropical forests in South America, Africa, India, and Southeast Asia

Bodies have many vertebrae, long ribs, no limbs

Feed primarily on worms and small underground invertebrates

Typhlonectes Compressicauda



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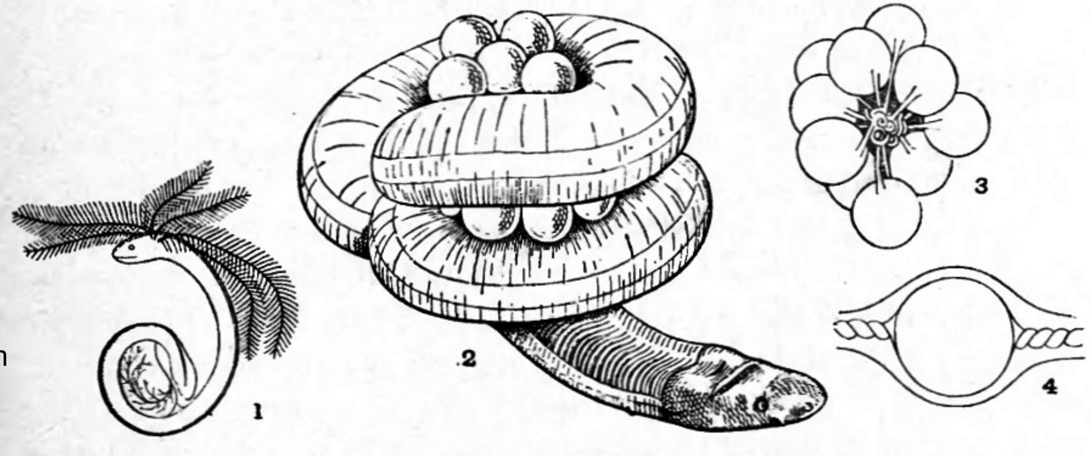

Fig. 15.—*Ichthyophis glutinosa* × 1. (After P. and F. Sarasin.) 1, A nearly ripe embryo, with gills, tail-fin, and still with a considerable amount of yolk; 2, female guarding her eggs, coiled up in a hole underground; 3, a bunch of newly laid eggs; 4, a single egg, enlarged, schematised to show the twisted albuminous strings or chalazae within the outer membrane, which surrounds the white of the egg.

By Hans Gadow - Gadow, Hans (1909) Amphibia and reptiles. MacMillan and Co., Public Domain, https://commons.wikimedia.org/w/index.php?curid=1962004

CAECILIAN

ORDER CAUDATA– SALAMANDERS AND NEWTS

360 + species.

Characteristics

- Tailed
- Typically small (15 cm or less)
- Usually aquatic larvae and terrestrial adults
- PAEDOMORPHOSIS in some species
- Carnivorous as both larvae and adults

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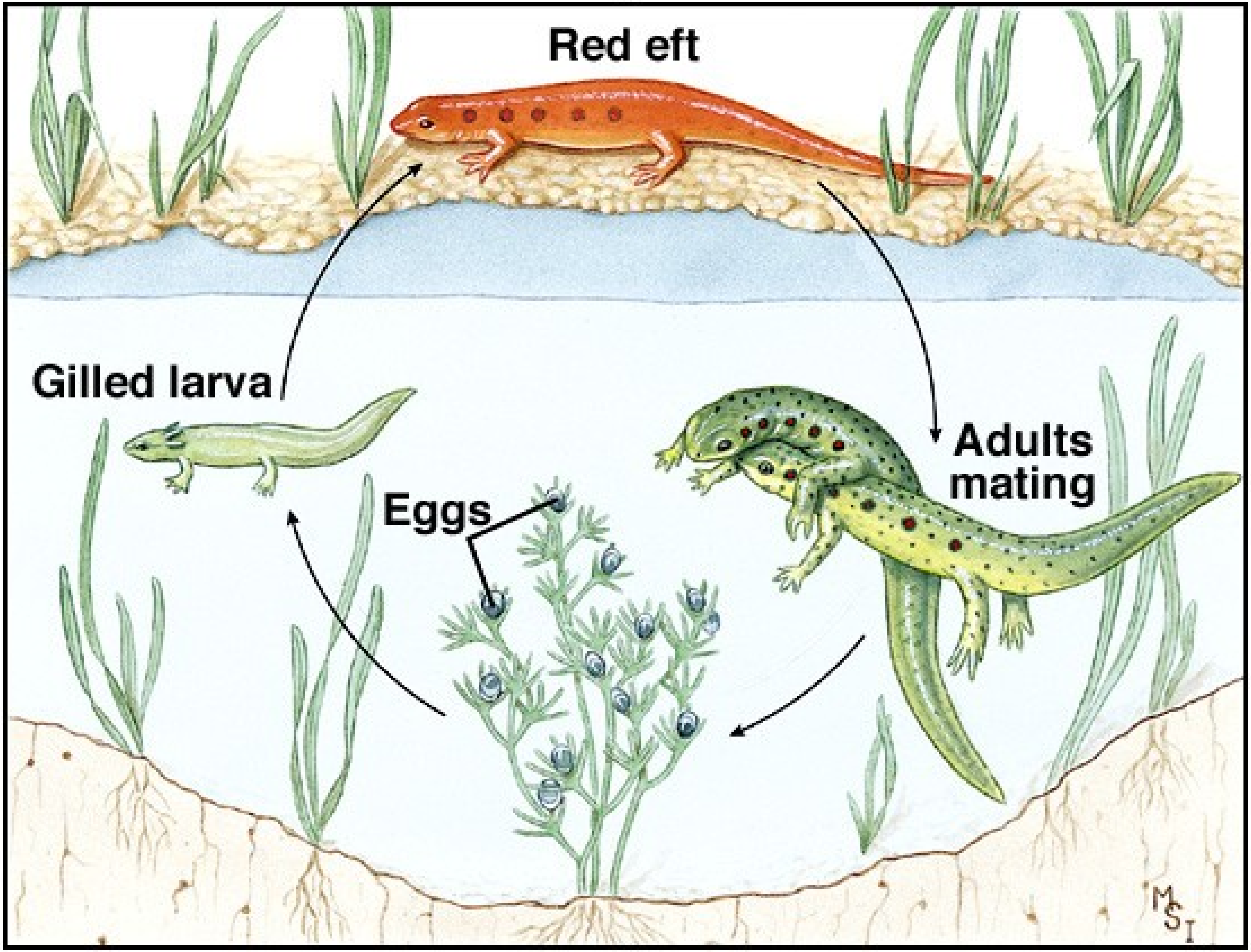
Life history of a newt



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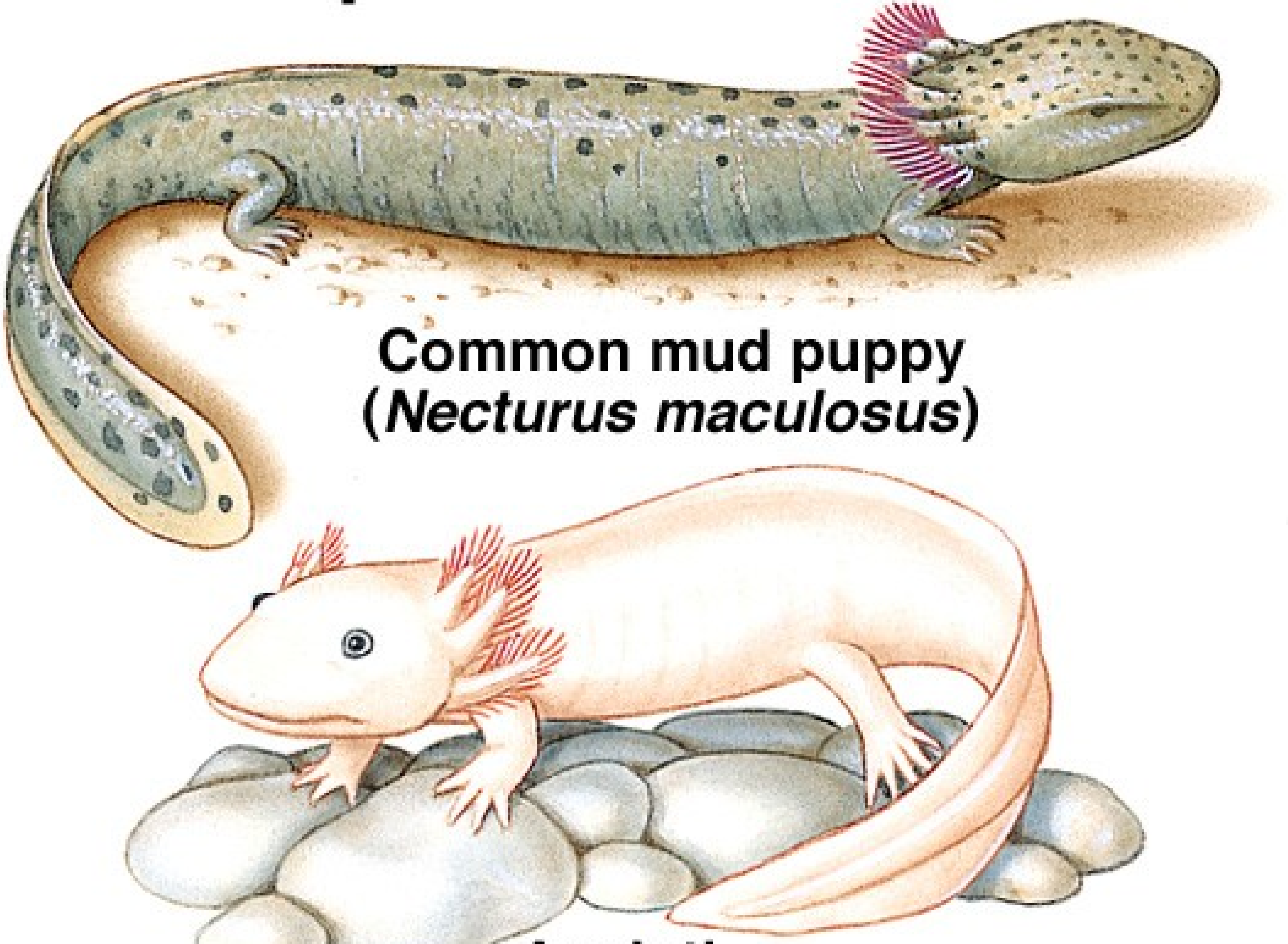
Paedomorphosis in salamanders



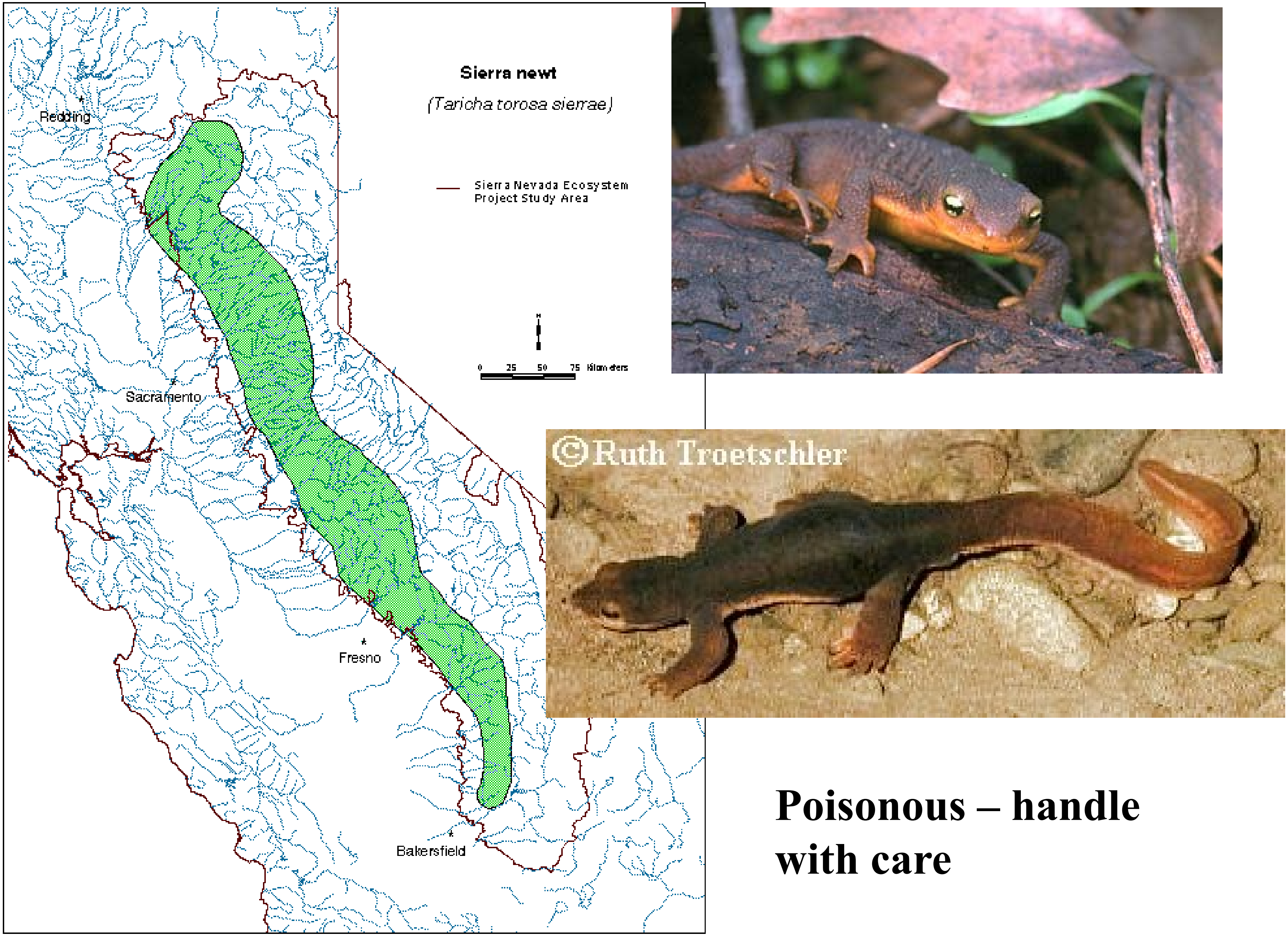
Common mud puppy
(*Necturus maculosus*)

Axolotl
(*Ambystoma mexicanum*)

MODERN AMPHIBIANS

In Mexico and the U.S.

- *Ambystoma tigrinum* may stay in a gilled stage as an *axolotl*
- When ponds dry up, may metamorphose into a terrestrial form and migrate to a new pond



Poisonous – handle with care

Japanese Giant Salamander Video

- http://news.nationalgeographic.com/news/2009/12/091231-salamander-video-wcvin.html

ORDER ANURA – FROGS AND TOADS

~ 3,500 species.

CHARACTERISTICS

- Tails absent in adults
- Egg 🗳 larva (TADPOLE) 🗳 adult
- Head and trunk fused together
- 6-10 vertebrae, with UROSTYLE
- Fertilization external, aquatic, AMPLEXUS

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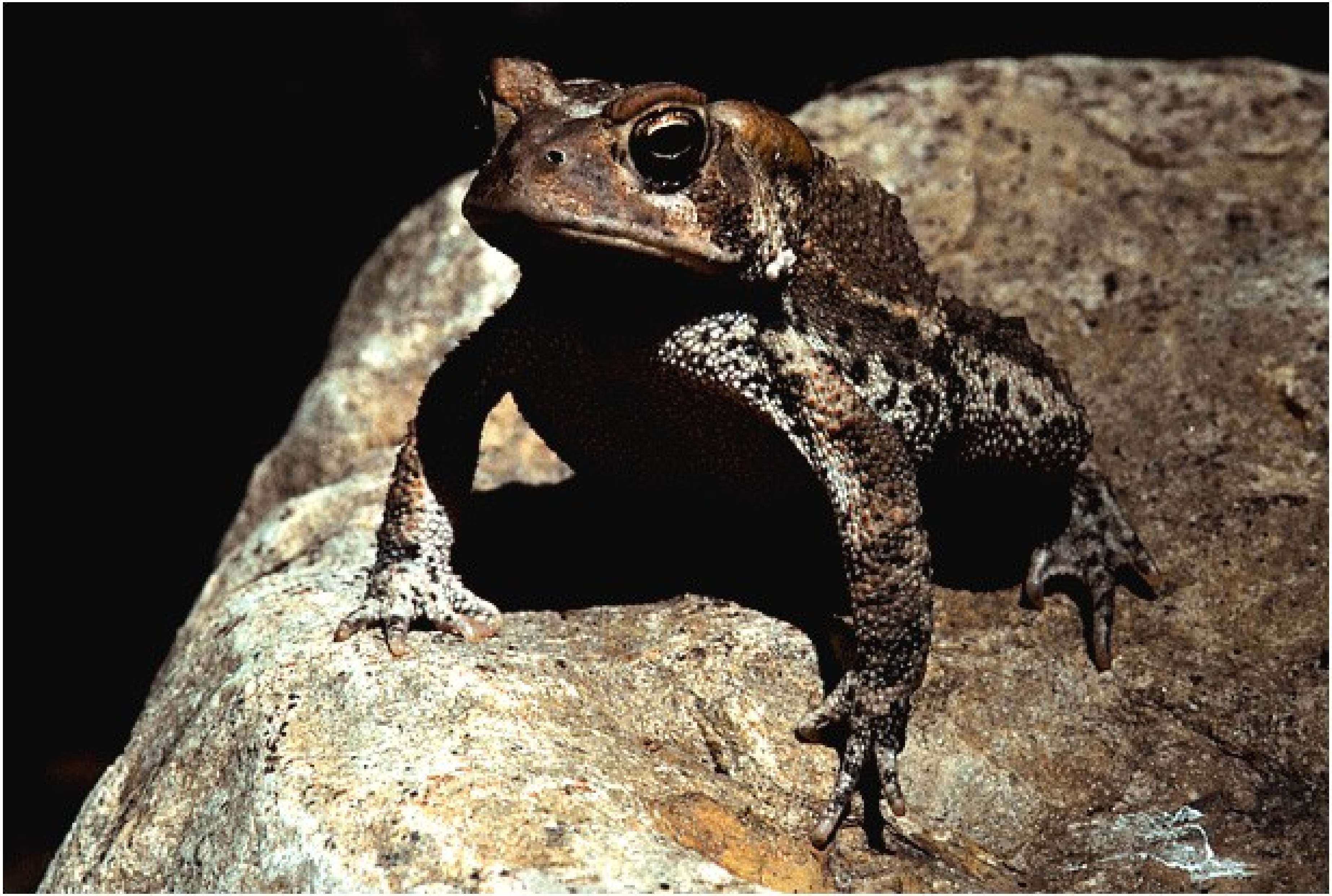
American toad (*Bufo americanus*)



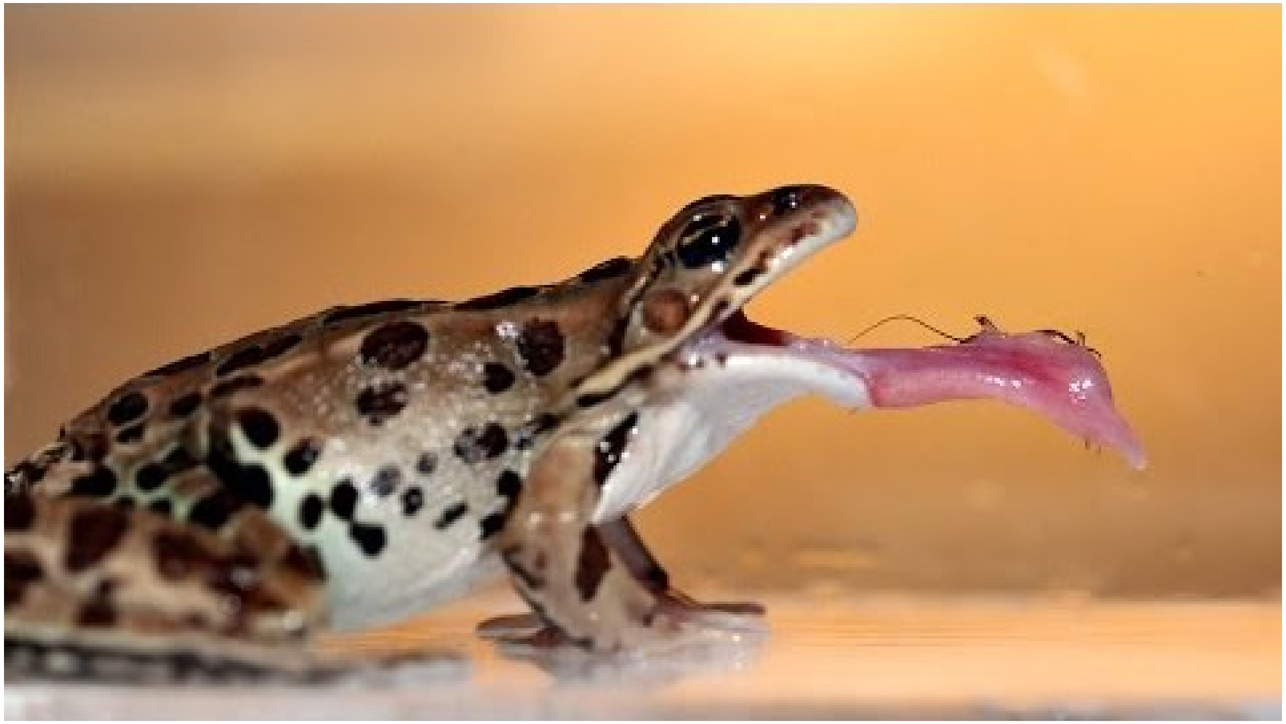
Cleveland P. Hickman, Jr.

MODERN AMPHIBIANS

Feeding and Digestion

- Most adult are *carnivorous*
  - Feed on insects, spiders, worms, slugs, etc.
- Catch prey with a tongue that is *attached at the front of mouth*
- Free end of tongue is glandular
  - *Sticky secretion adheres to prey*
- Any teeth that are present function to hold prey
  - *Do not bite or chew*
- Short digestive tract
- Larval stages of tadpoles are *usually herbivorous*
  - Digestive tract is relatively long

Frog tongues



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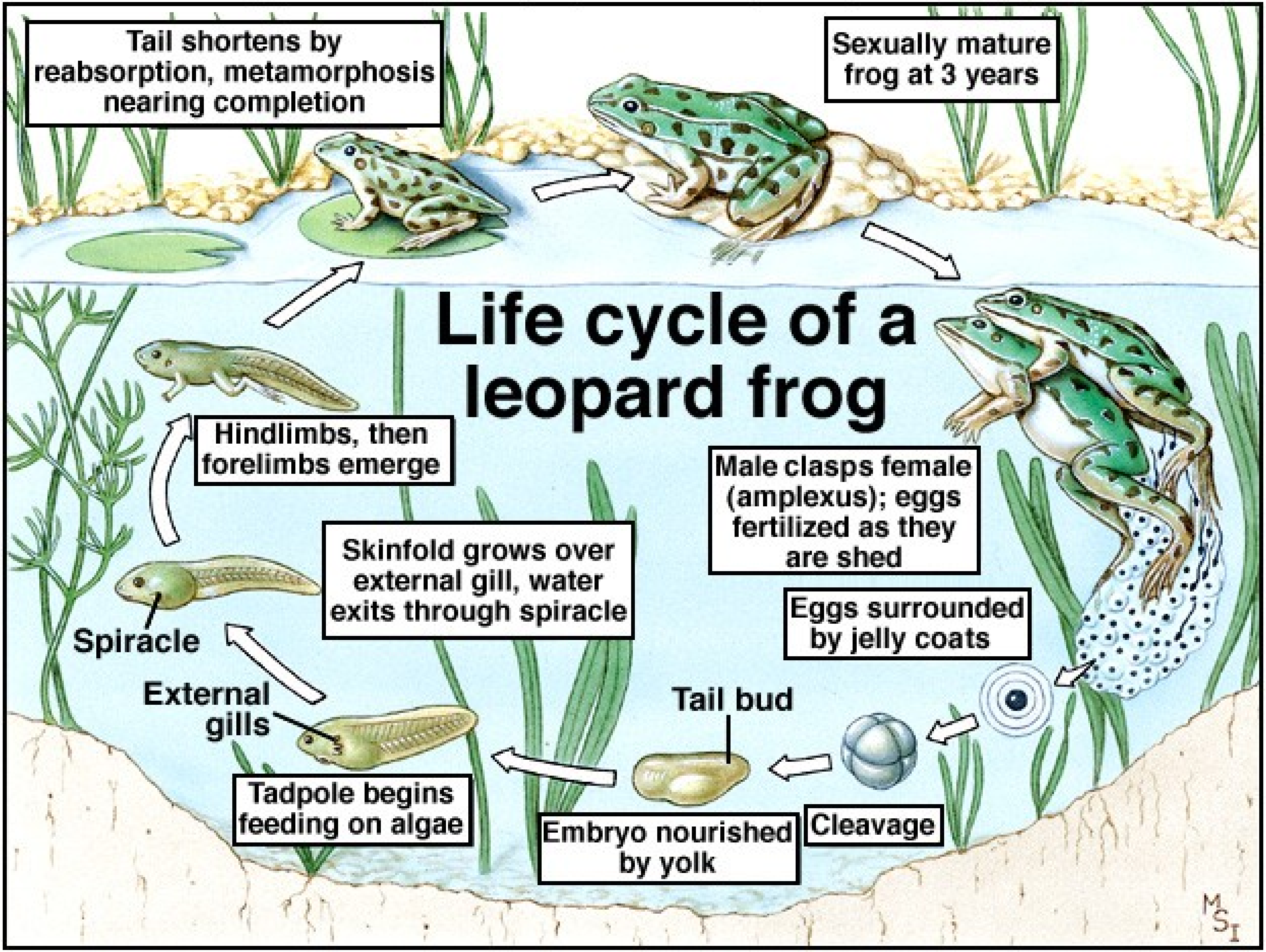


Life cycle of a leopard frog

Tail shortens by reabsorption, metamorphosis nearing completion

Sexually mature frog at 3 years

Hindlimbs, then forelimbs emerge

Male clasps female (amplexus); eggs fertilized as they are shed

Skinfold grows over external gill, water exits through spiracle

Eggs surrounded by jelly coats

Tadpole begins feeding on algae

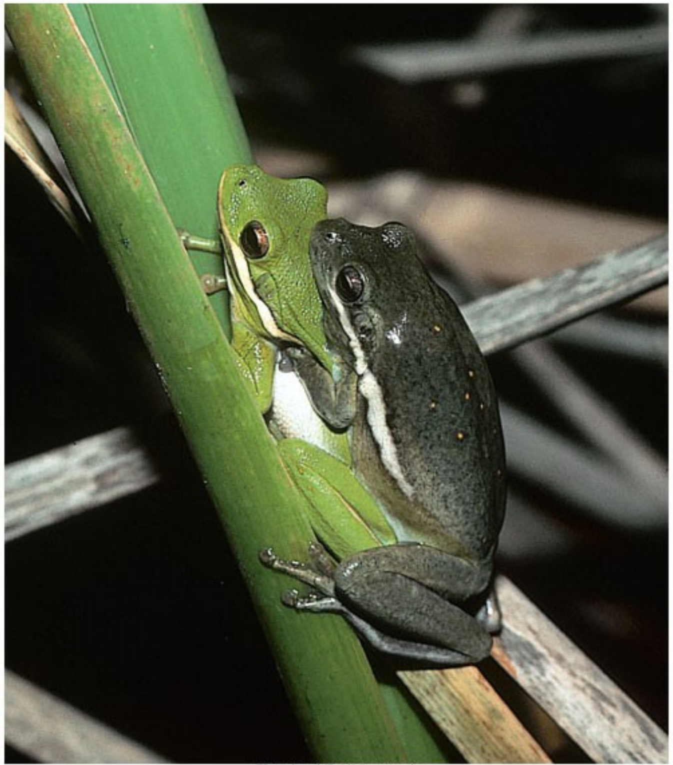
Embryo nourished by yolk

Cleavage

MODERN AMPHIBIANS

Life Cycle

- Most larger frogs are solitary until breeding season
- During breeding season, males are especially noisy when trying to attract a female



Cleveland P. Hickman, Jr.

Amplexus

In spring, males call to attract females When eggs are mature, females enter the water and the males clasp them in *amplexus.*

After fertilization, jelly layers of egg absorb water and swell.

Eggs usually laid in large masses.

Development begins *immediately.*

Tadpole may hatch in 6–9 days.

NOISY FROGS

MODERN AMPHIBIANS

- Eggs of most hatch into tadpoles with a long, finned tail, no legs, gills and specialized mouthparts for herbivorous feeding
- Tadpoles look and act entirely different from adult frogs

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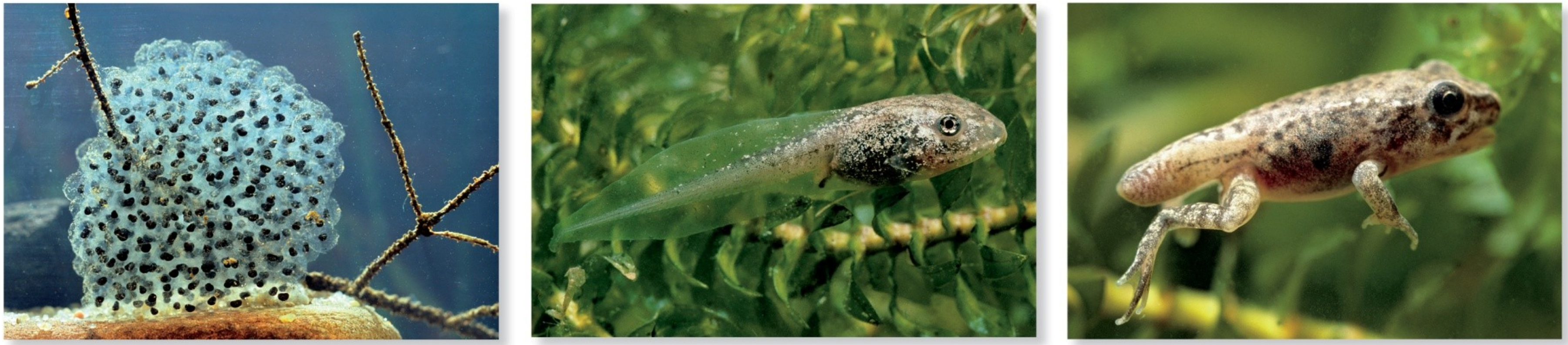
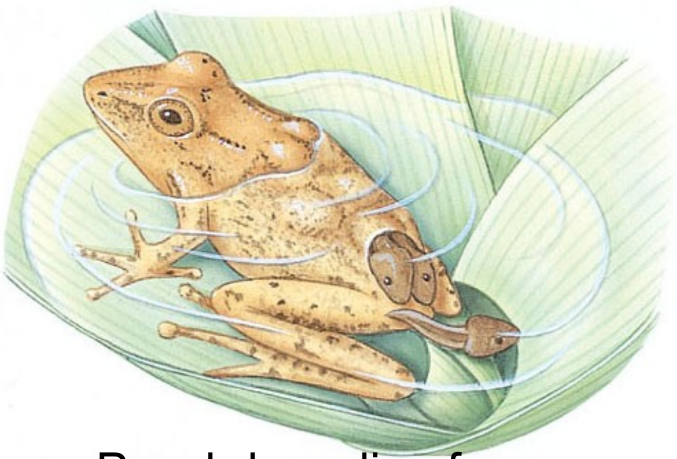
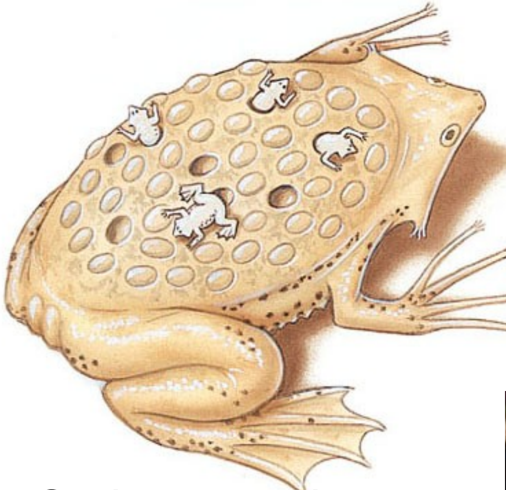


(a) Gelatinous mass of amphibian eggs **(b) Tadpole** **(c) Tadpole undergoing metamorphosis**

a: © Don Vail/Alamy; (b-c): © Dwight Kuhn

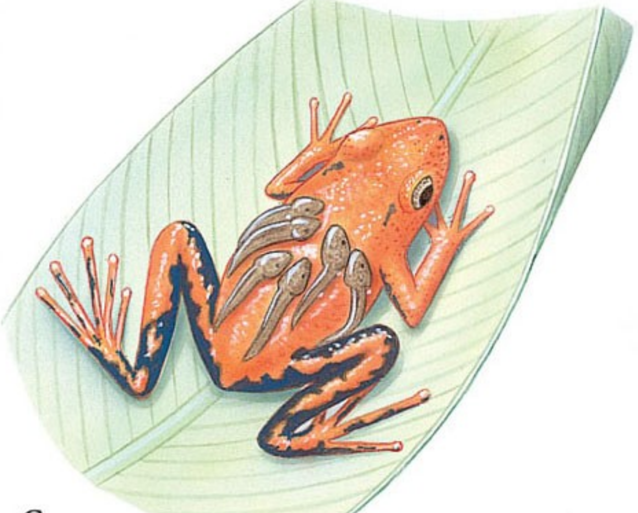


A Pouch-brooding frog. Known as a “marsupial frog”, may transfer oxygen and nutrients within the vascularized pouch.

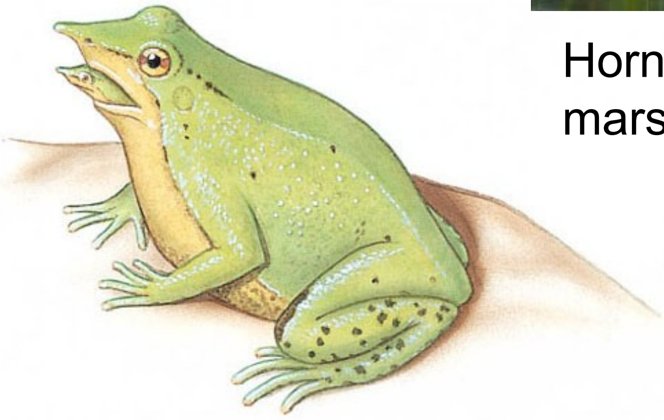


B Surinam toad

Horned marsupial frog

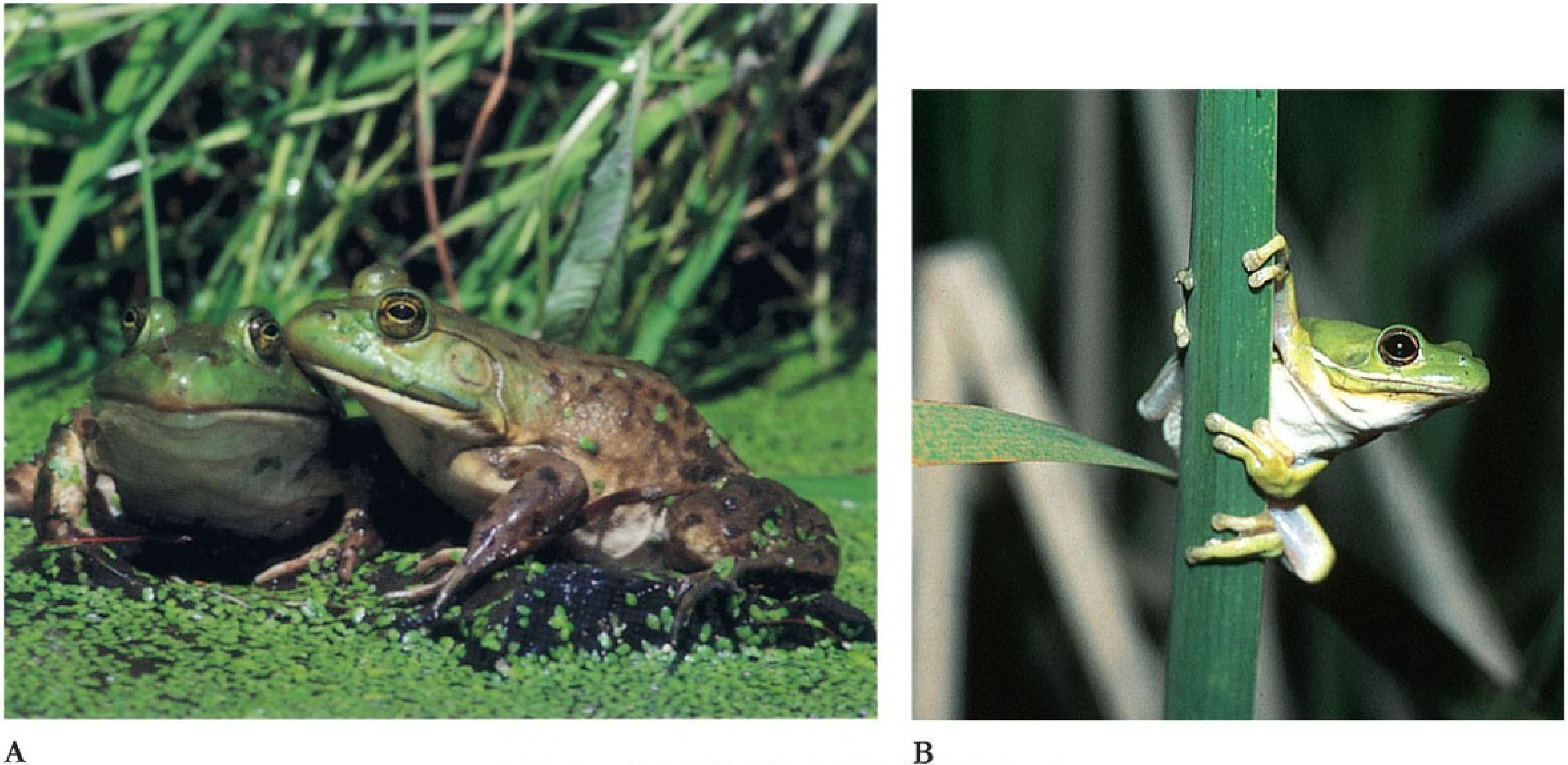


C Strawberry poison dart frog & others transporting babies up into the forest canopy in pool of bromeliad leaf, or to small pool of water in a crevice.



D Northern Darwin’s frog - The fungus *Batrachochytrium dendrobatidis* may have led to its extinction. Still have southern Darwin’s frogs (Chile, Argentina). Male carries tadpoles in vocal sack.

SURINAM TOAD



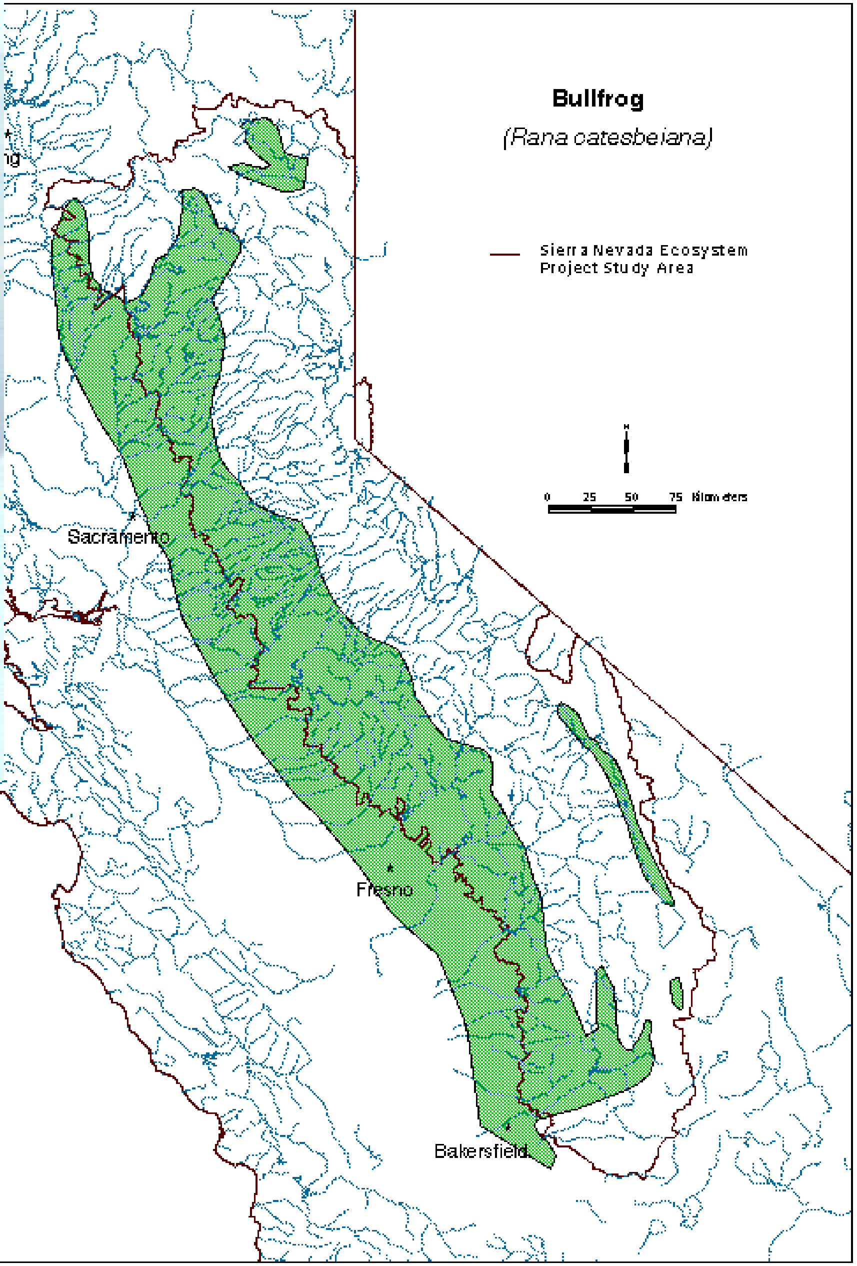
A: © Ken Lucas/Biological Photo Service; B: Cleveland P. Hickman, Jr.

bullfrogs

Treefrog with adhesive pads

BULLFROGS – INTRODUCED TO CA – BUT EAT OTHER NATIVE FROGS. “GAPE-LIMITED PREDATOR” = IF IT FITS IN THEIR MOUTH, THEY WILL EAT IT!

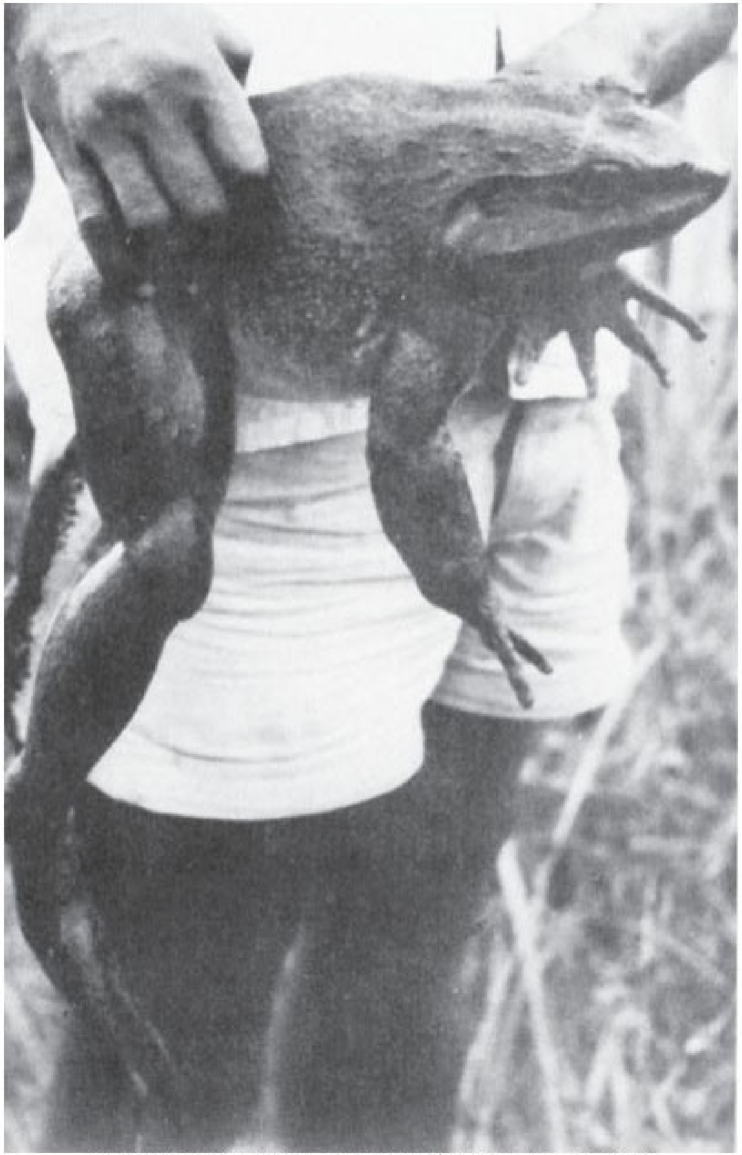
© Digital Frog International



[Frogs of California]

Cleveland P. Hickman, Jr.

African Clawed Frog, a pest species in CA



Courtesy American Museum of Natural History, Neg. #125617

World’s largest frog from West Africa 7.5 pounds

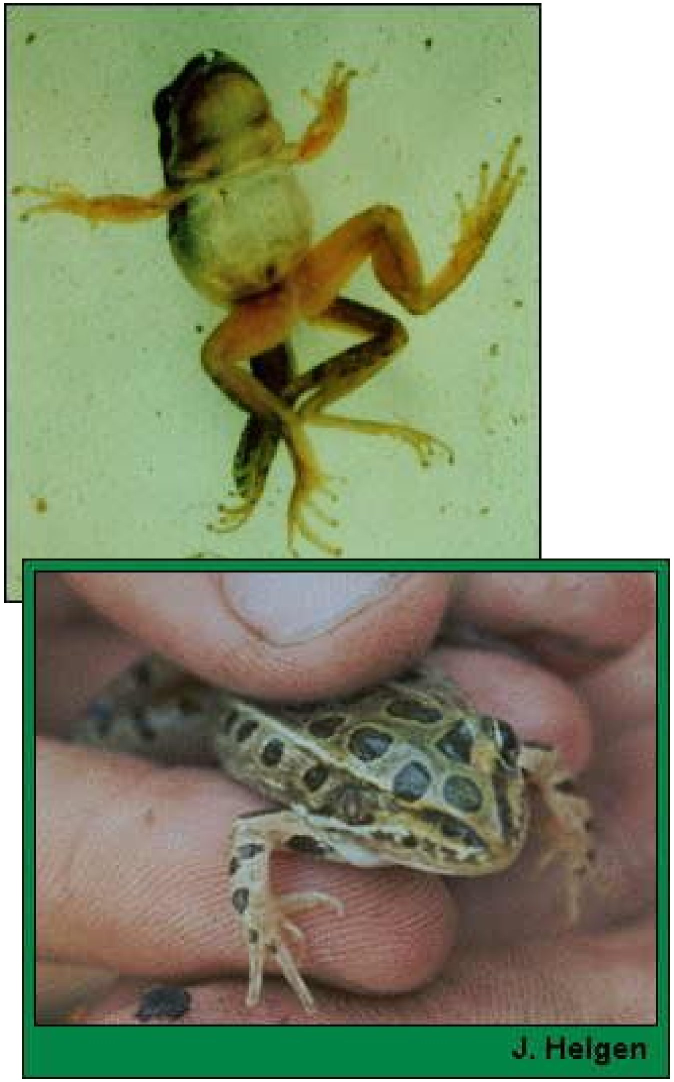
GLASS FROG

MODERN AMPHIBIANS

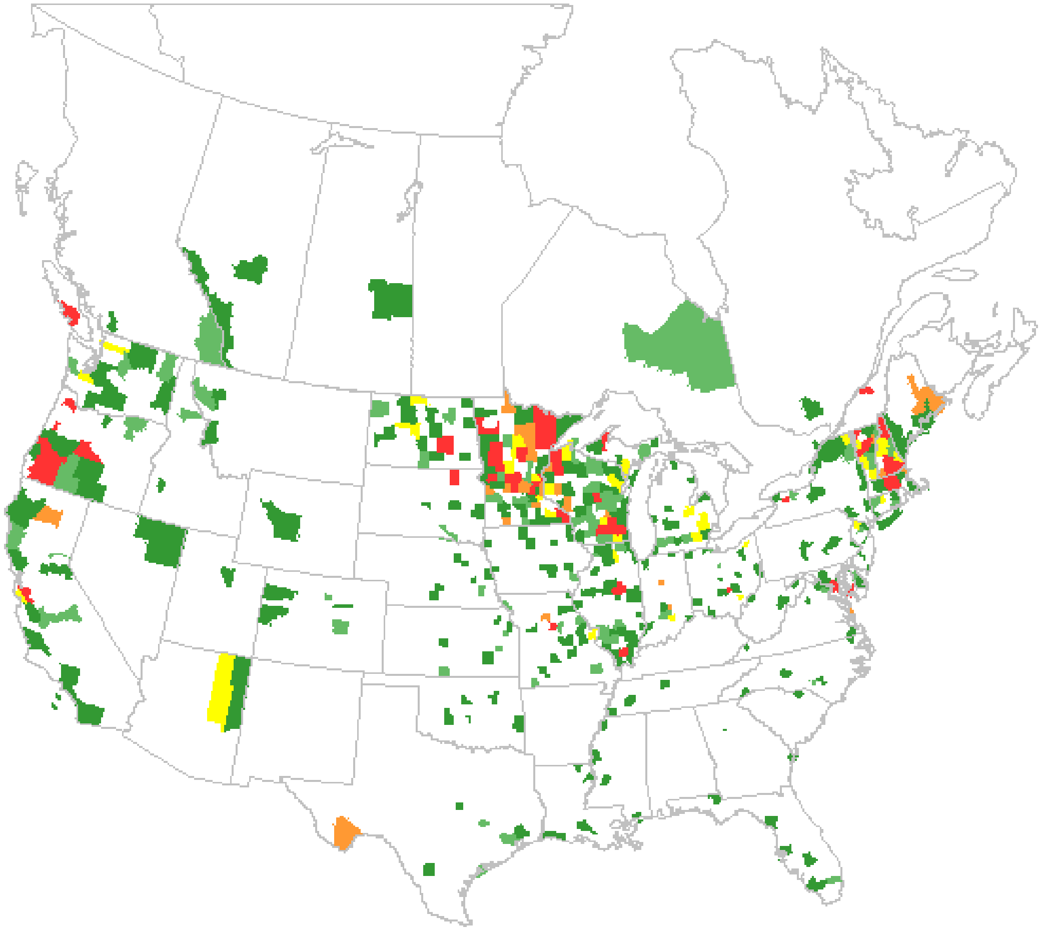
Hibernation

- During winter in temperate climates
    - Hibernate in soft mud in bottom of pools, get oxygen through their skin
    - Some frogs in the desert “hibernate” underground in summer, so they don’t dry out
- *Frost-tolerant frogs*
    - Have glucose and glycerol in body fluids (anti-freeze)
    - Protection from damaging effects of ice-crystal formation
- Many are easy prey
- Many species have suffered from changes in the environment and climate brought about by *humans*

Amphibian decline and malformations - global issue



J. Helgen



MODERN AMPHIBIANS

Specialized pigment cells, *chromatophores,* produce skin color in frogs

- color to match with background and *camouflage themselves*
- Some defend themselves with poison glands – these have warning coloration

NATIONAL GEOGRAPHIC
Photograph by Christian Ziegler

DECEPTIVE ANIMALS, AUGUST 2009

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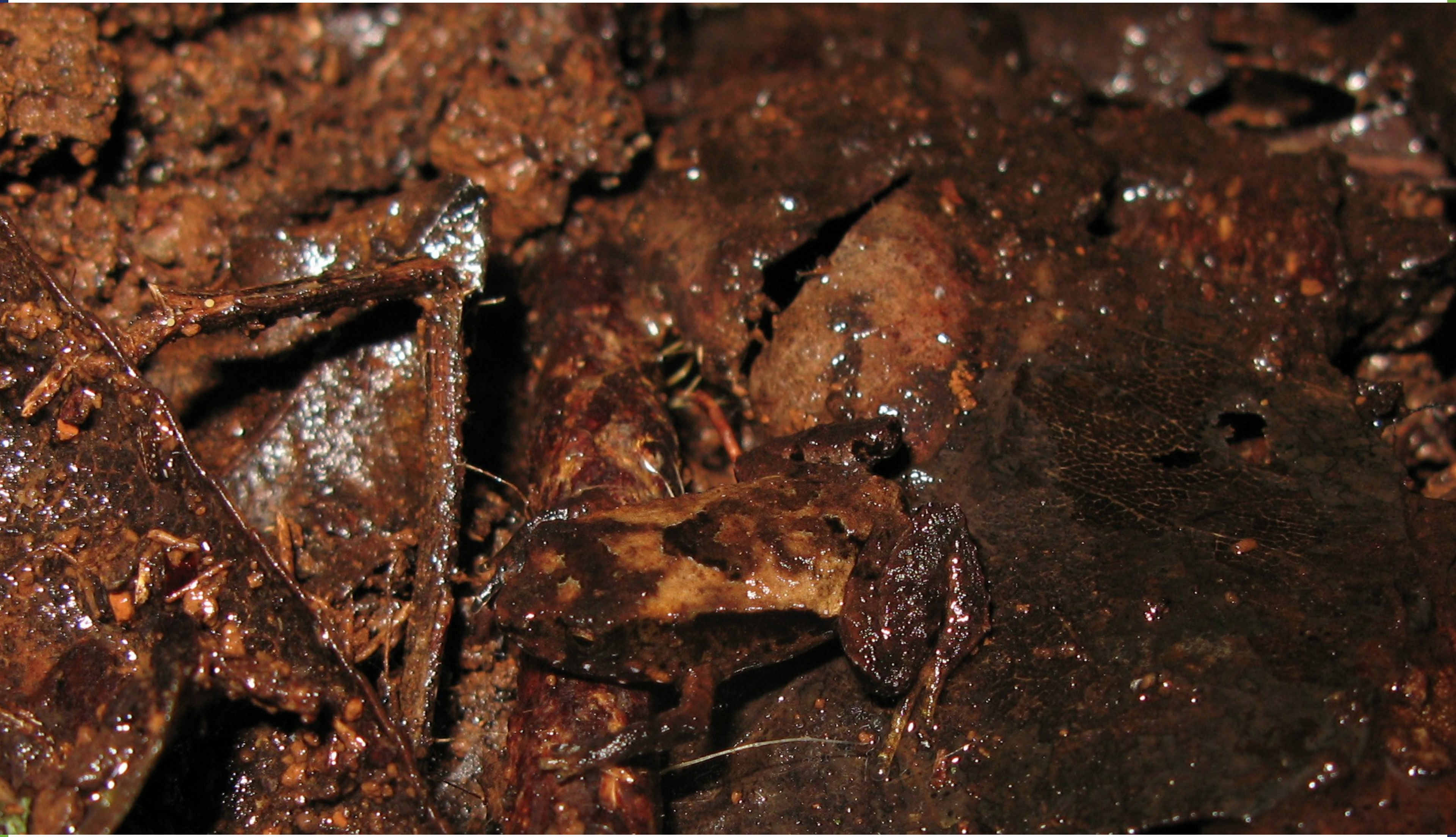

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Amniotes: Tetrapods with a Desiccation-Resistant Egg

Critical innovation was the development of a **shelled egg** that sheltered the embryo from desiccating conditions on land

Amniotic egg broke tie to water

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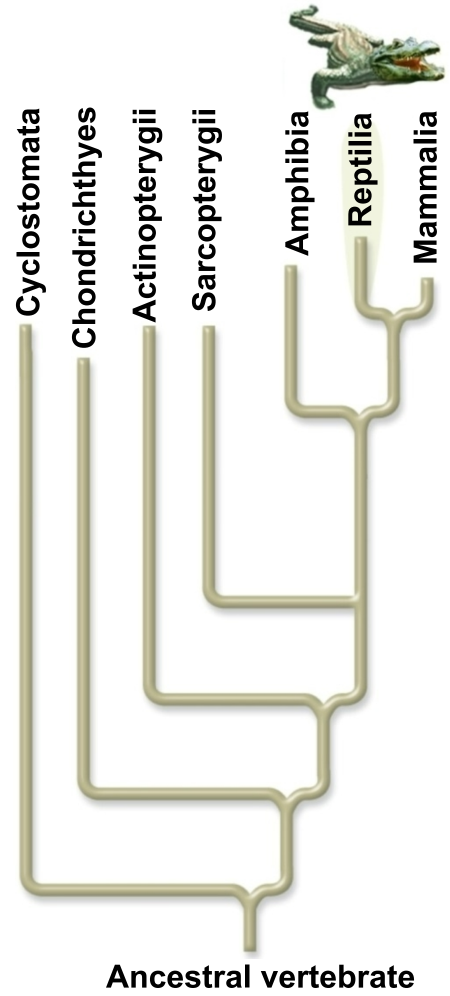

Evolution of the amniotes

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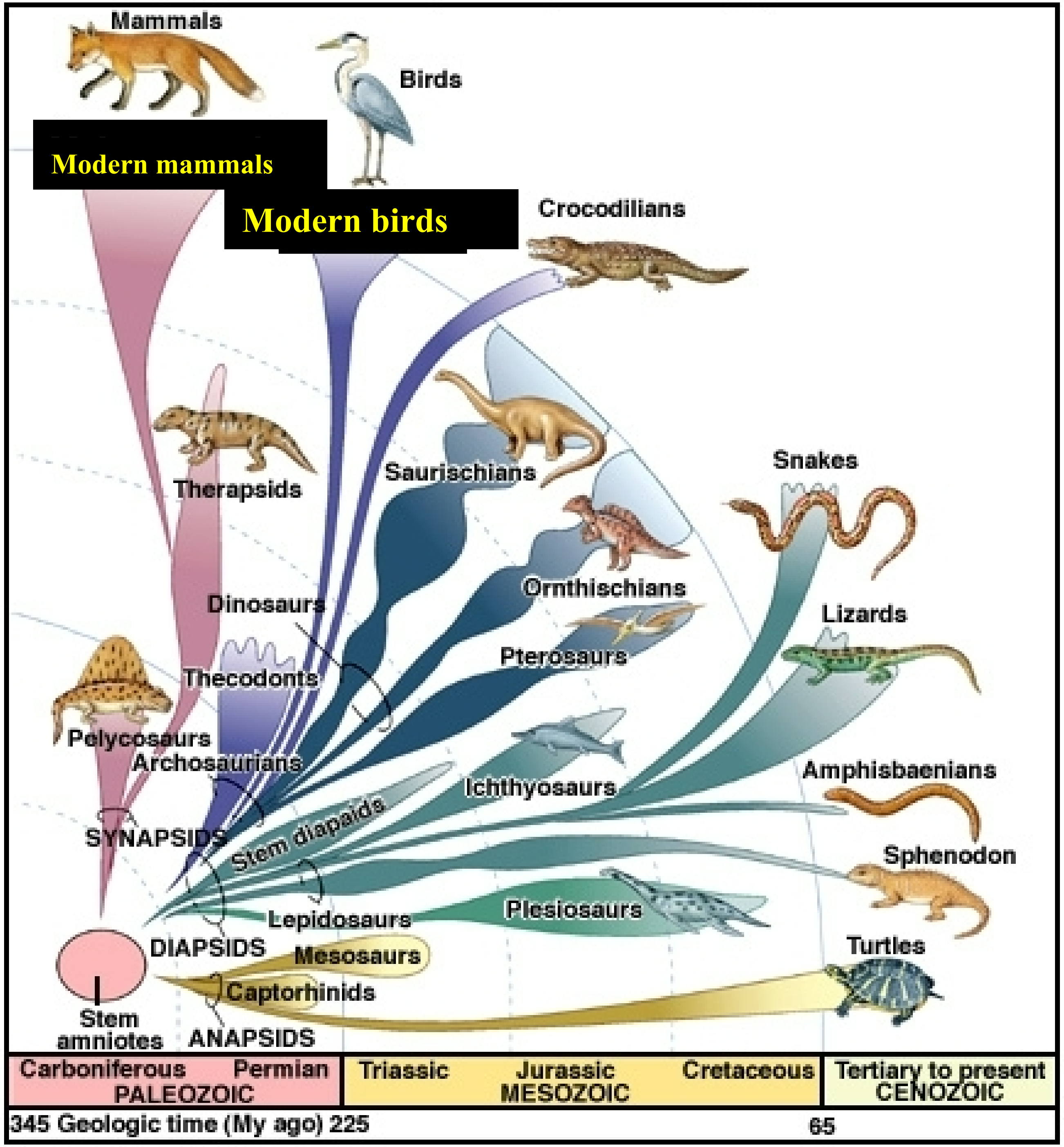

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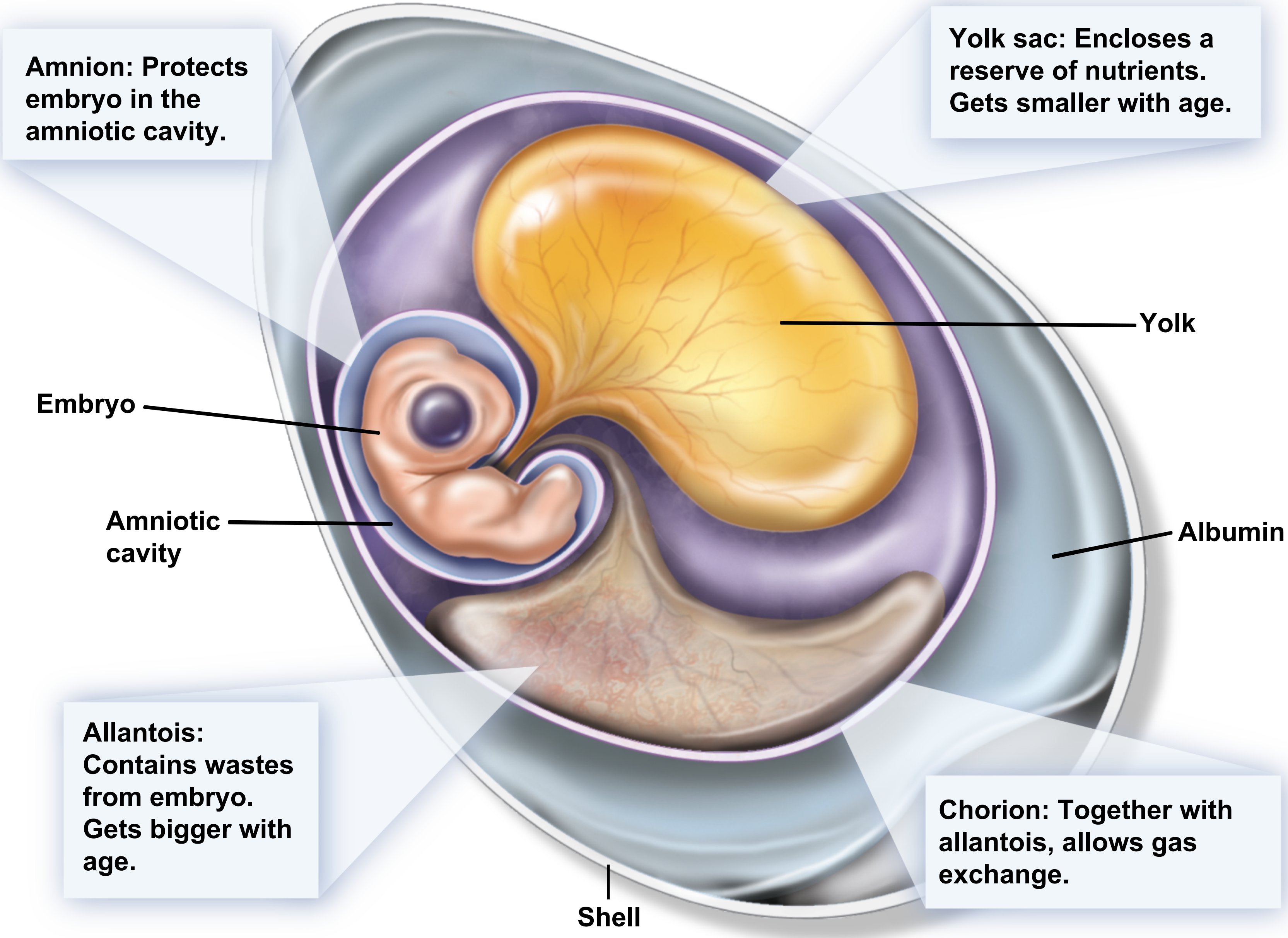


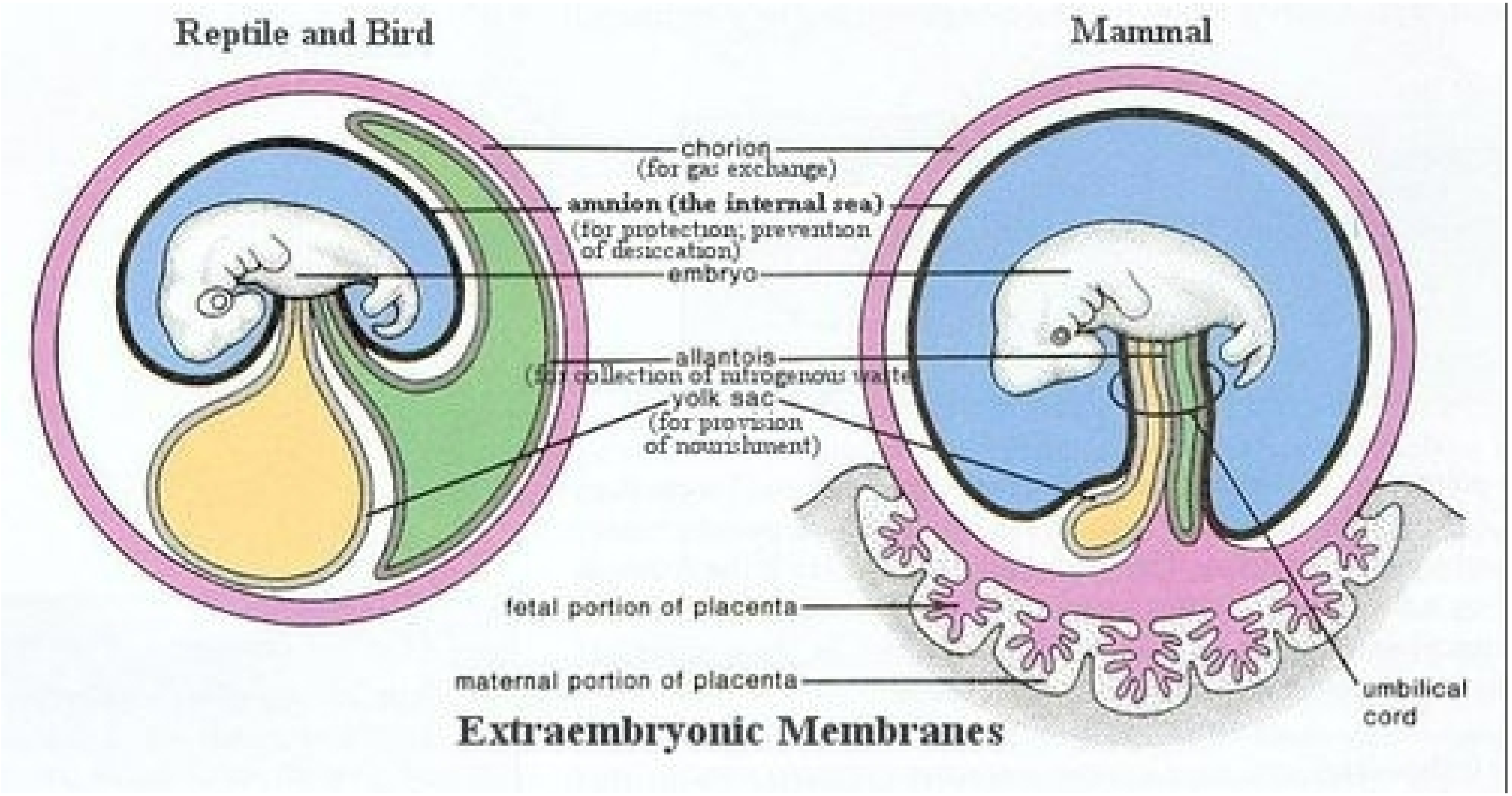
Amnion: Protects embryo in the amniotic cavity.

Yolk sac: Encloses a reserve of nutrients. Gets smaller with age.

Allantois: Contains wastes from embryo. Gets bigger with age.

Chorion: Together with allantois, allows gas exchange.

EGG MEMBRANES & PLACENTAL MEMBRANES


Reptile and Bird
Mammal
chorion
(for gas exchange)
amnion (the internal sea)
(for protection; prevention of desiccation)
embryo
allantois
(for collection of nitrogenous waste)
yolk sac
(for provision of nourishment)
fetal portion of placenta
maternal portion of placenta
umbilical cord

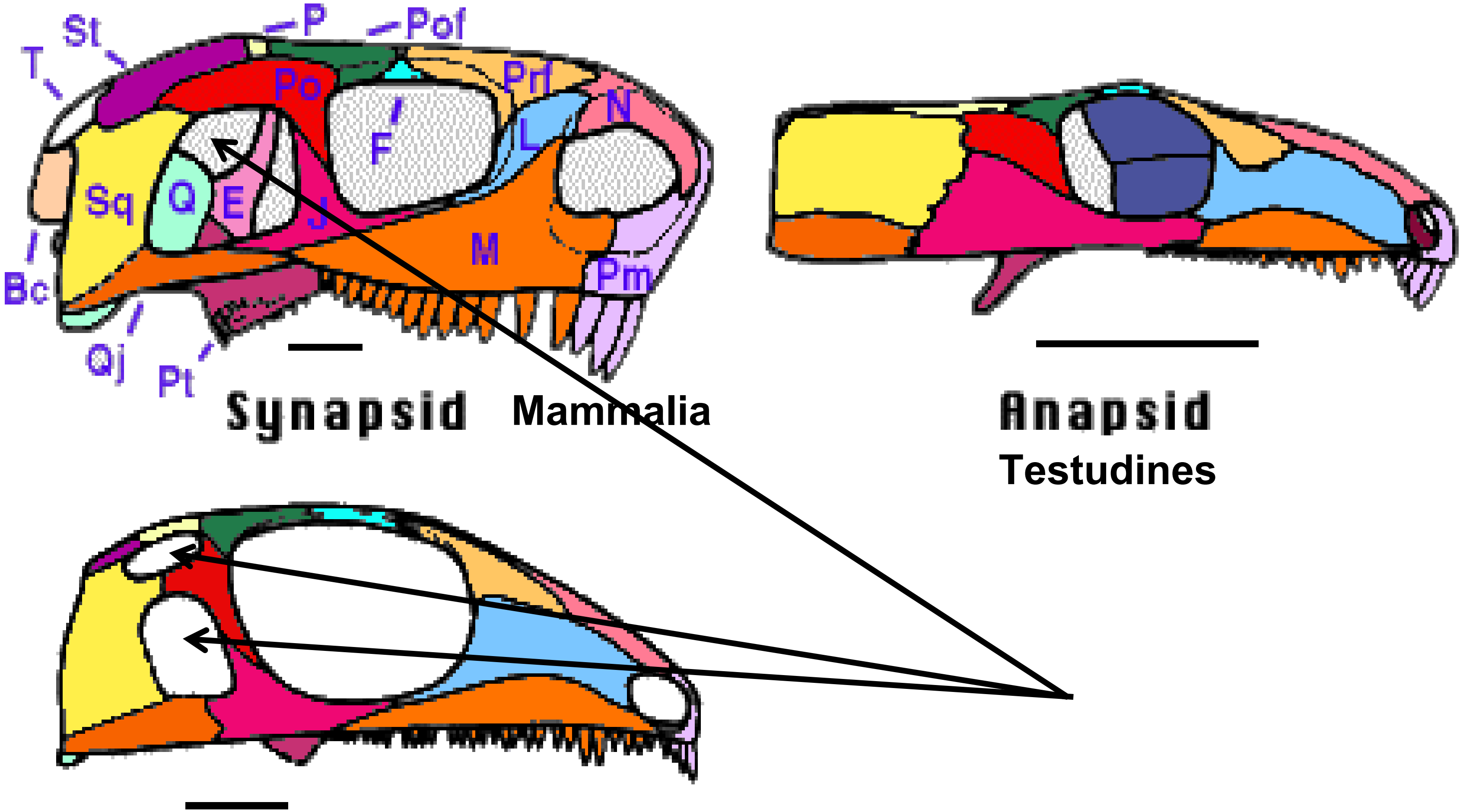
Extraembryonic Membranes

AMNIOTE SKULL STRUCTURE

Anapsid – no temporal openings in the skull – Turtles are the only living anapsids

Diapsid – two temporal openings in the skull: Lizards and snakes, tuatara, crocs, and living birds

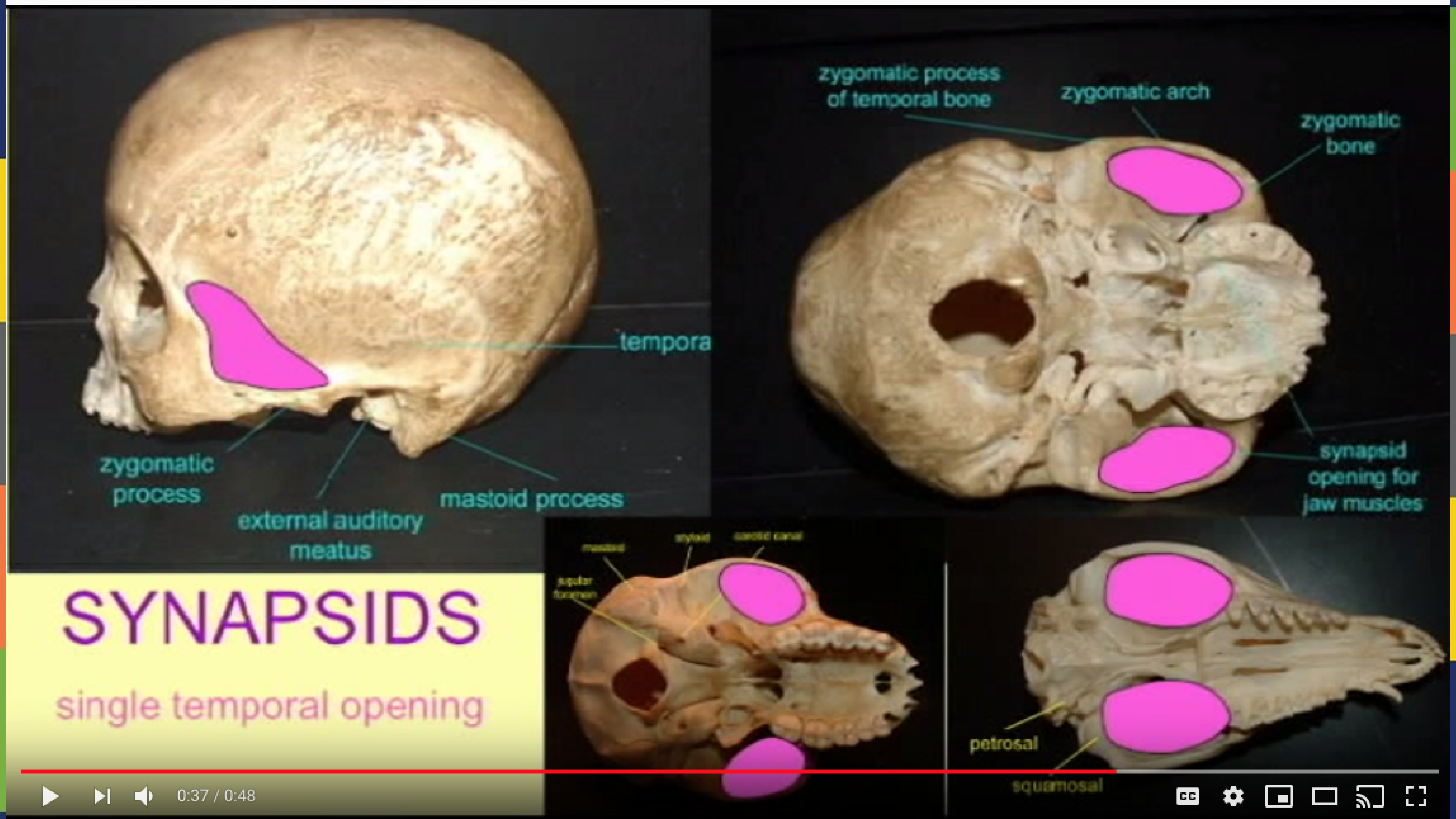
Synapsid – one temporal opening: living mammals



Synapsid Mammalia

Anapsid
Testudines

Diapsid Reptiles (- turtles)



SYNAPSIDS

single temporal opening

LIVING ON DRY LAND

Amniotic eggs – covered with shell – don’t dry out

Other key innovations for living on drier land:

- ❑ Desiccation resistant skin - scales

Other key innovations for living on drier land:

- **Desiccation resistant skin**
- **Thoracic breathing** – negative pressure sucks air in

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- Water-conserving **kidneys** – concentrate waste prior to elimination

Other key innovations for living on drier land:

- **Desiccation resistant skin**
- **Thoracic breathing** – negative pressure sucks air in
- Water-conserving **kidneys** – concentrate waste prior to elimination
- **Internal fertilization – WHY necessary??**

Other key innovations for living on drier land:

- **Desiccation resistant skin**
- **Thoracic breathing** – negative pressure sucks air in
- Water-conserving **kidneys** – concentrate waste prior to elimination
- **Internal fertilization**

Traditional classification has three living amniotes – **reptiles, birds** and **mammals**

- **Birds are part of the reptilian lineage**

DINOSAURS

Class **Ornithischia** – bird-hipped dinosaurs

Class **Saurischia** – lizard-hipped dinosaurs

Legs of dinosaurs were positioned directly under the body

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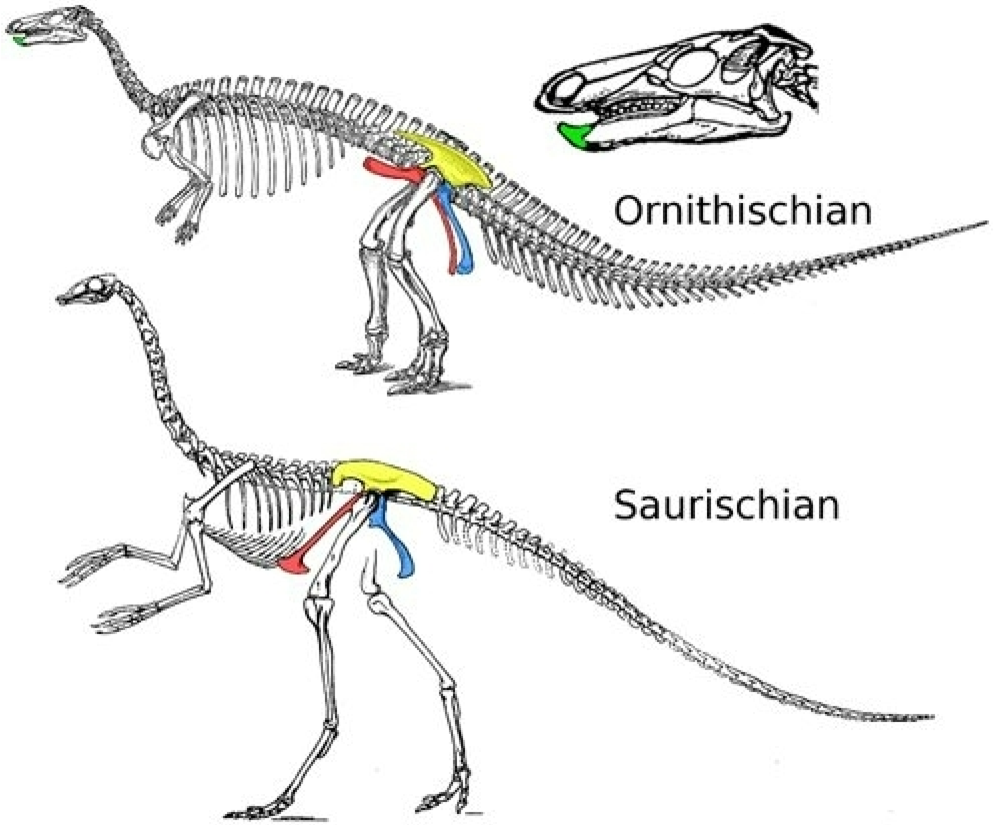
(a) Ornithischian (*Stegosaurus*) **(b) Saurischian (*Tyrannosaurus*)**



Archaeopteryx lithographica

- Related to therapods group of saurischian dinosaurs

Caudipteryx zoui

Confuciusornis sanctus

- Completely feathered, lacking bony tail and toothed jaw

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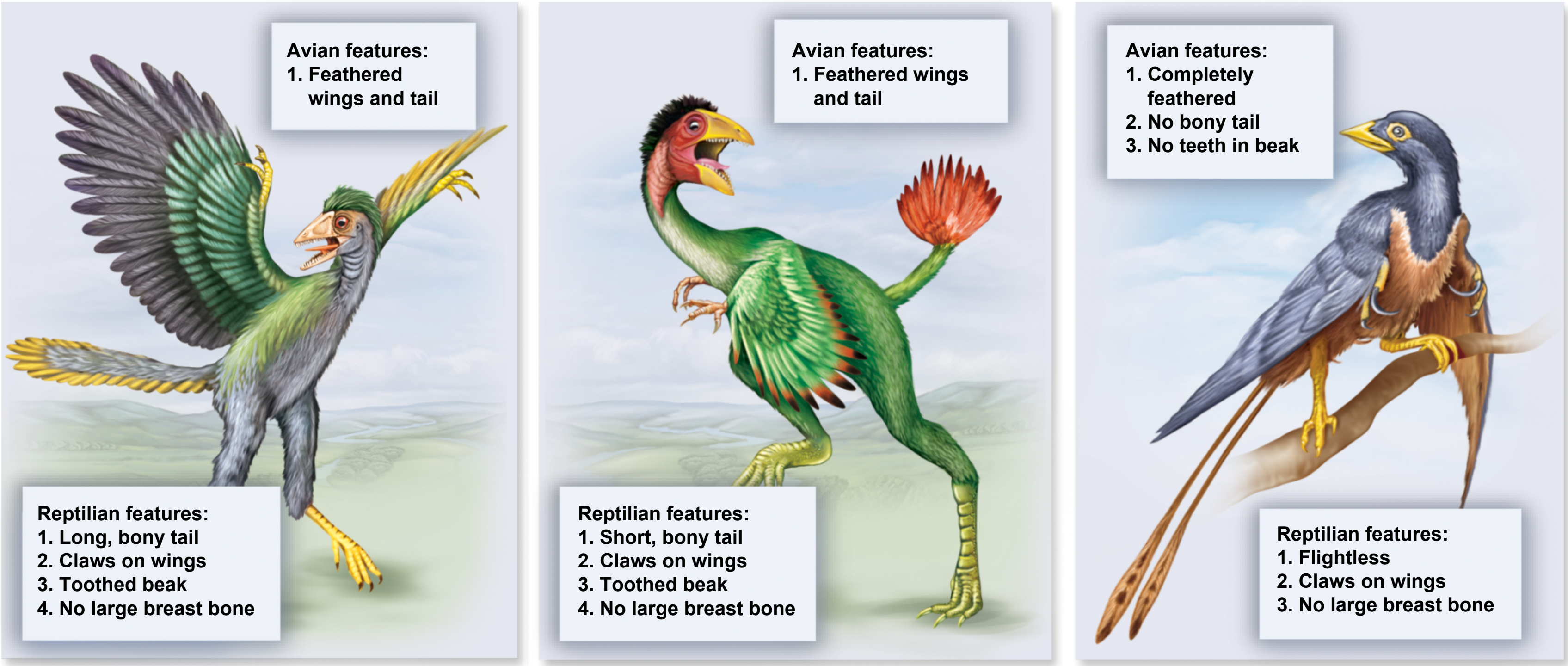


Avian features:
1. Feathered wings and tail

Reptilian features:
1. Long, bony tail
2. Claws on wings
3. Toothed beak
4. No large breast bone

Avian features:
1. Feathered wings and tail

Reptilian features:
1. Short, bony tail
2. Claws on wings
3. Toothed beak
4. No large breast bone

Avian features:
1. Completely feathered
2. No bony tail
3. No teeth in beak

Reptilian features:
1. Flightless
2. Claws on wings
3. No large breast bone

(a) *Archaeopteryx lithographica*

(b) *Caudipteryx zoui*

(c) *Confuciusornis sanctus*

CRANIATA – CLASS REPTILIA – THE REPTILES: TURTLES, SNAKES AND LIZARDS, CROCODILIANS, (BIRDS)

18,000 + species (7,700 + traditional reptiles, 10,000 birds)

CHARACTERISTICS OF REPTILES

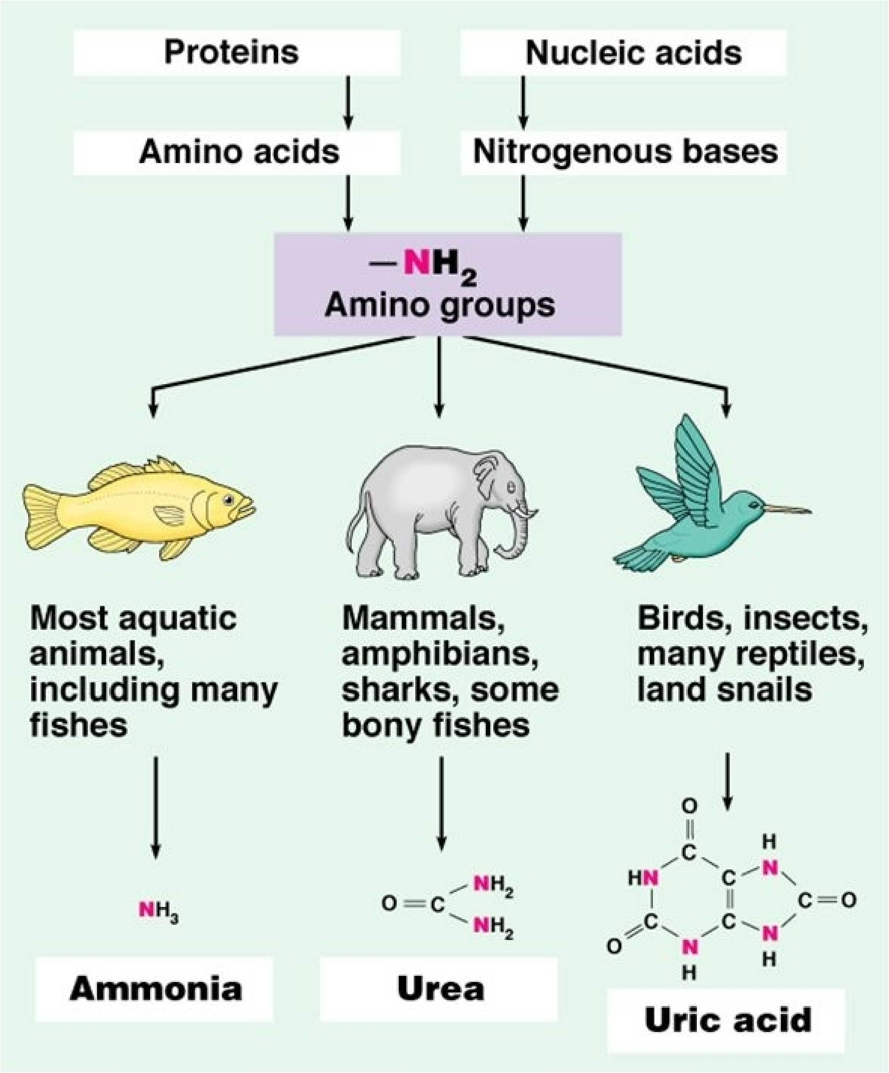
- **Body covered with keratin epidermal scales, sometimes with bony plates (fish scales form in the dermis)**
- **Paired limbs with (usually) five toes: absent in snakes and some lizards**
- **Ribs with STERNUM (breastbone): forms a thoracic cage**
- **Lungs**
- **3-chambered heart: crocodilians with a 4-chambered heart**
- **Ectothermic**
- **Paired kidneys: uric acid waste** $C_5H_4N_4O_3$
- **Internal fertilization**
- **SHELLED EGGS – calcareous or leathery. Extra-embryonic membranes – AMNION, CHORION, ALLANTOIS. NO larvae.**

EXCRETORY WASTE TYPES

Excretion:

Disposal of Nitrogenous Wastes

- ammonia is too toxic to be stored
- land animals must dispose of Nitrogen in different form: Urea or Uric Acid
- Urea can be stored in conc'd. form but requires water for disposal
- Uric acid allows for water conservation



Proteins

Amino acids

Nucleic acids

Nitrogenous bases

$-NH_2$
Amino groups

Most aquatic animals, including many fishes

Mammals, amphibians, sharks, some bony fishes

Birds, insects, many reptiles, land snails

NH_3

Ammonia

$O=C(NH_2)_2$

Urea

Uric acid

TAXONOMY (LIVING TAXA ONLY)

TESTUDINES - (turtles)

SAURIA

- **Lepidosauria**
  - **Sphenodonta (*Sphenodon*)= Tuatara**
  - **SQUAMATA (snakes and lizards)**
- **Archosauria**
  - **CROCODILIA (alligators and crocodiles)**
  - **AVES (birds)**

CLASS TESTUDINES

Turtles, tortoises and terrapins

Virtually unchanged for 200 million years

Hard protective shell

In most, vertebrae and ribs fused to shell

Lack teeth but have sharp beak

a: © Pat Morris/ardea.com

(a) Green turtle

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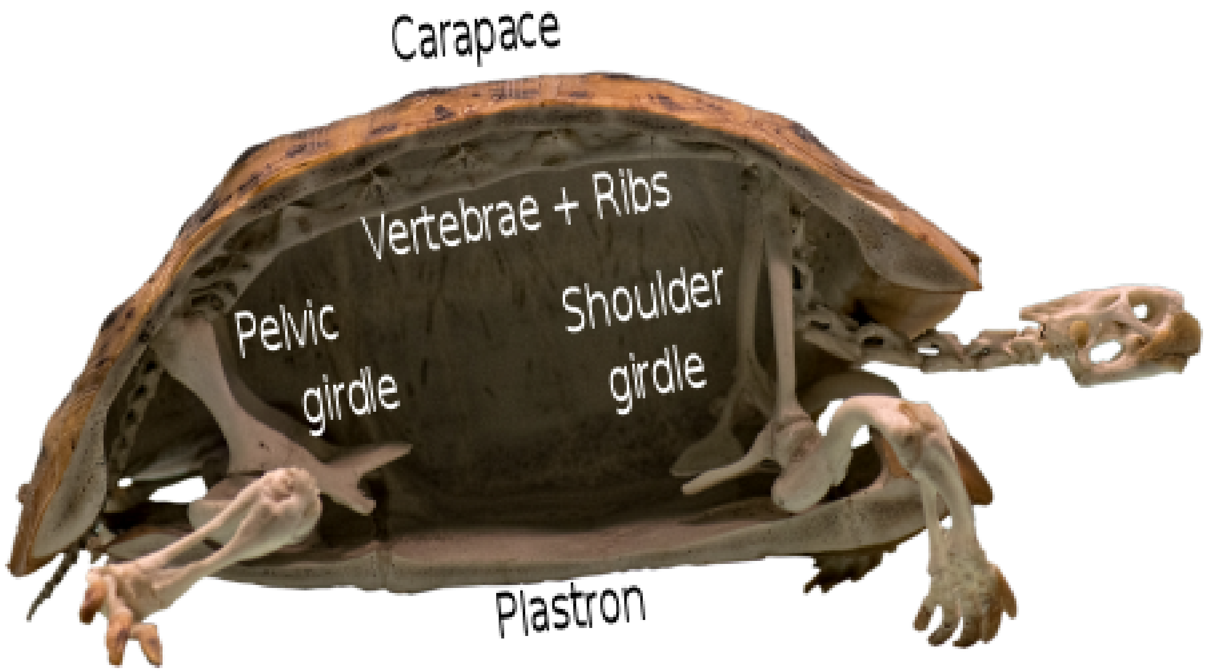


TURTLES

All lay eggs.

None provide parental care.

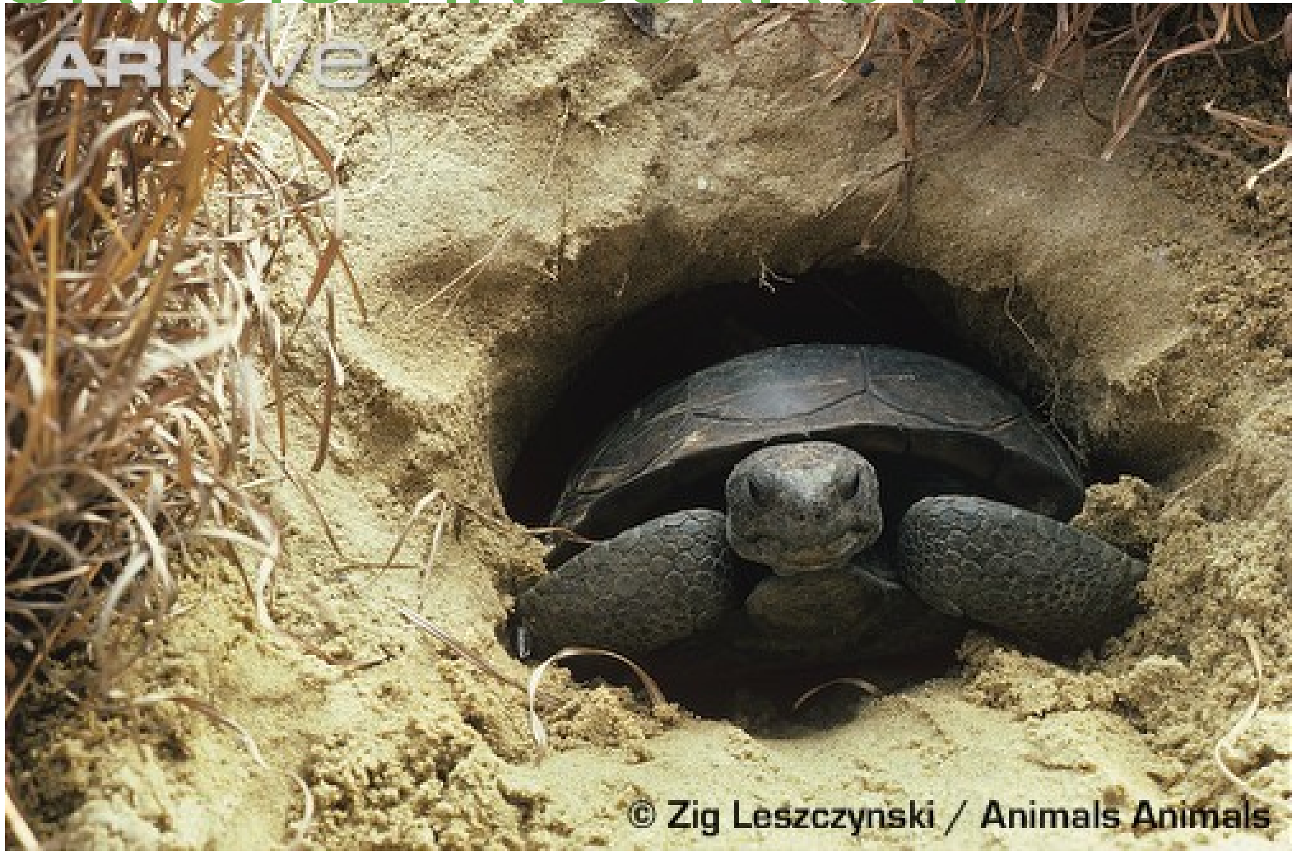
Body has a shell: shell shape reflects ecology:

- Medium, terrestrial forms, like box turtle, have medium domed shell, and flexible lower shell (plastron) that allow the front and back portions to close the opening of the shell.

GALAPAGOS TORTOISE

- Larger, terrestrial forms have high, domed shells.

GOPHER TORTOISE IN BURROW



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- Smaller, terrestrial burrowing forms have less domed shells.

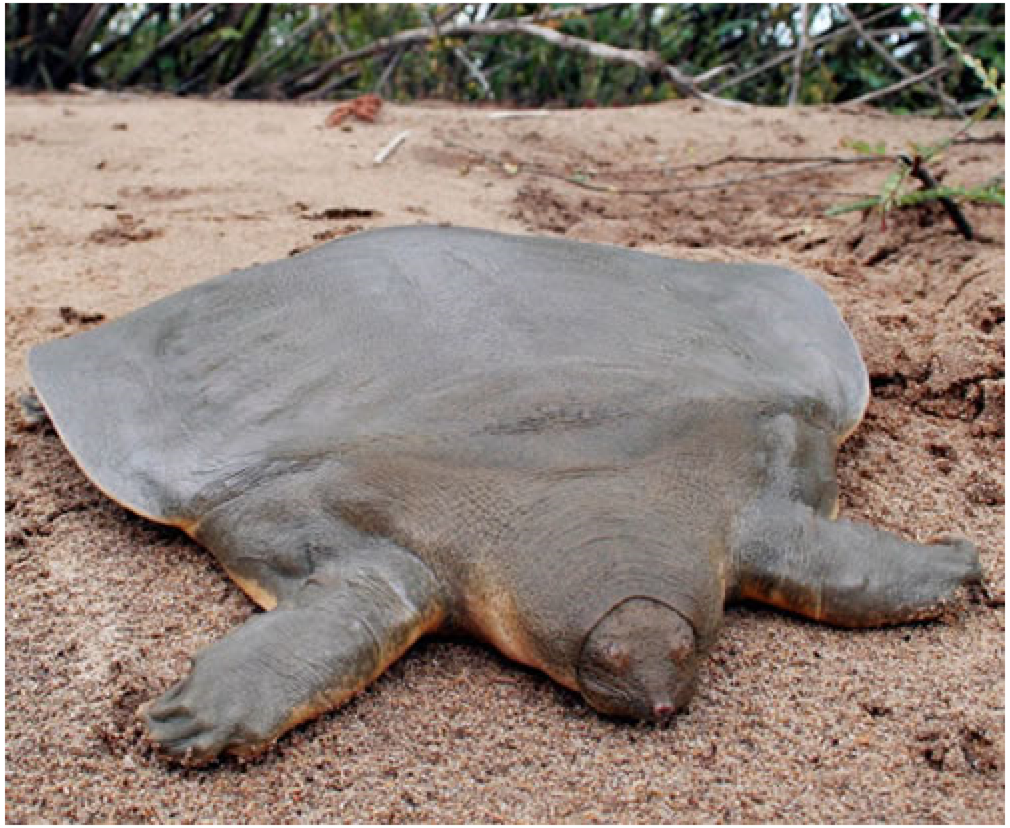
SEA TURTLE

Aquatic forms have low carapaces to reduce resistance when moving through water.

SNAPPING TURTLE

SOFT-SHELLED TURTLE

Fast swimmers. Reduced ossification of shell makes them lighter. Large feet with webbing.

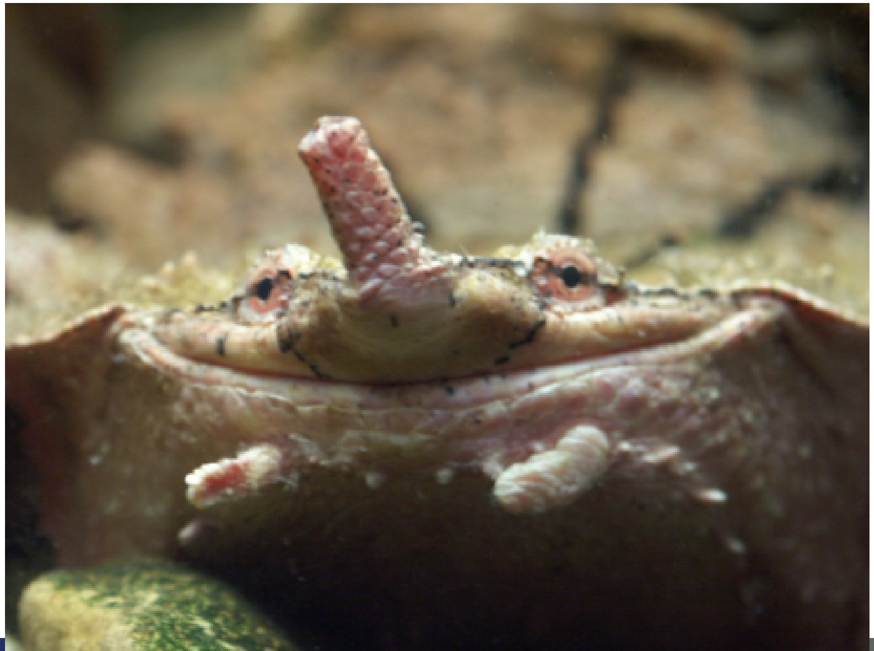


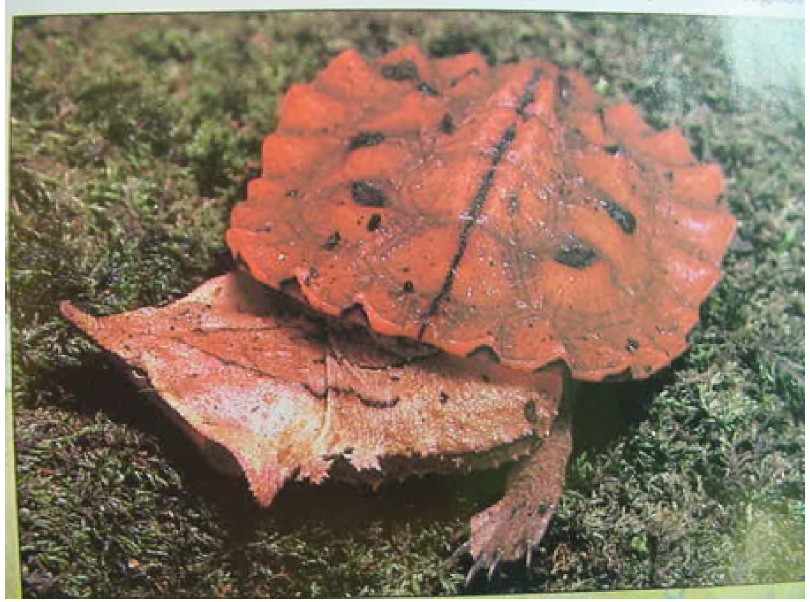
MATAMATA

South American

Cryptic

Lobes on head sensitive to vibrations of prey. Opens mouth, expands throat, food rushes in w/wa



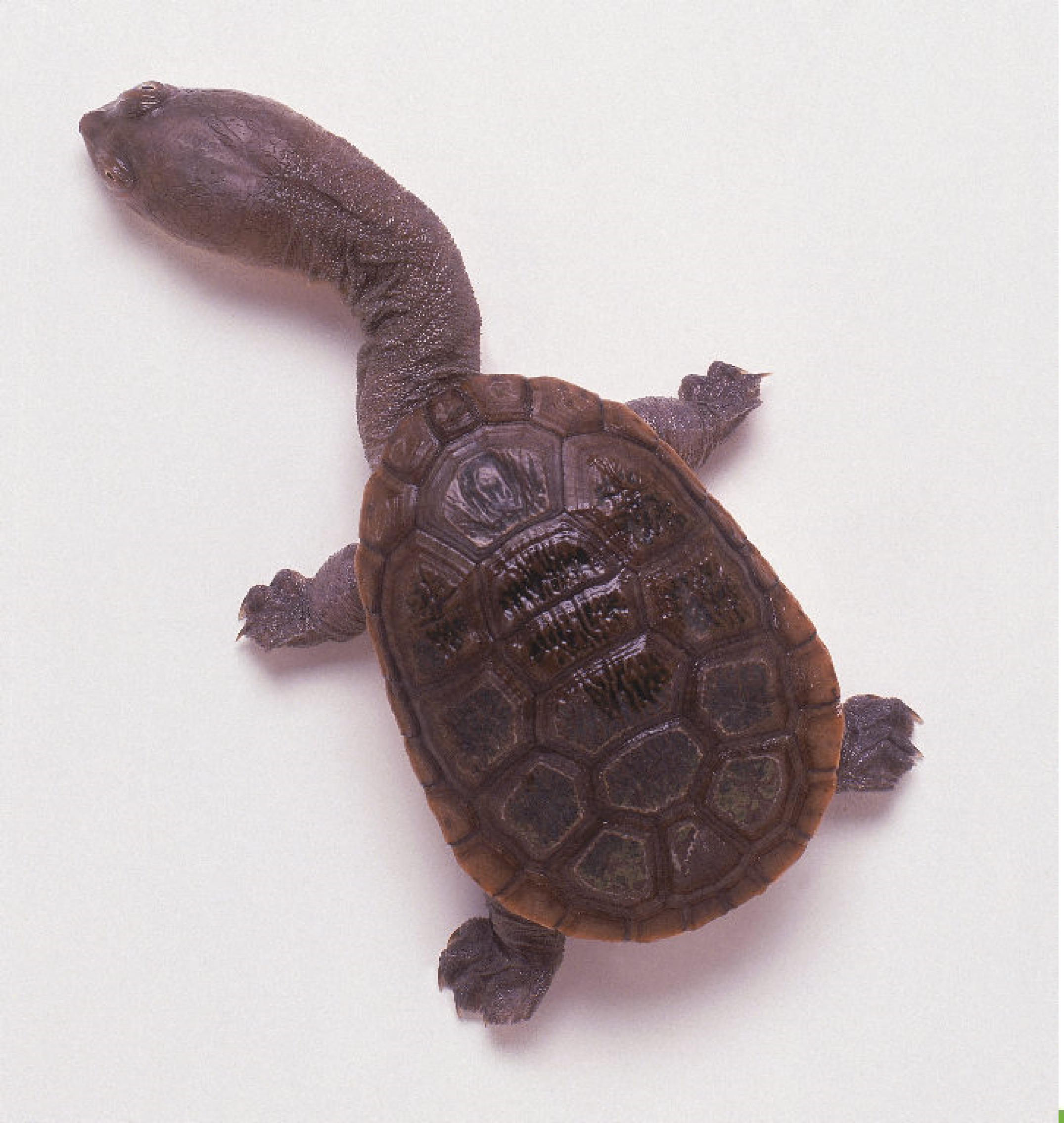


SNAKE-NECKED TURTLES

South America, Australia, New Guinea

Neck may be longer than body.

Catch fish with a sudden dart of head.



RESPIRATION

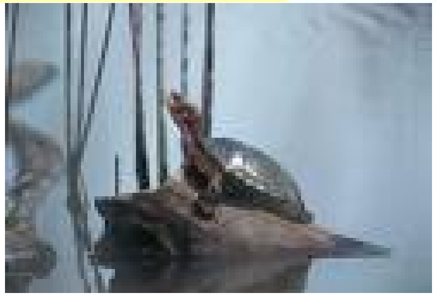
Lizards used ribcage movement to draw air into the lungs.

Turtles can’t, because of fused ribs and rigid shell.

Turtle lungs are attached to the carapace, and on the ventral side, the lungs are attached to connective tissue (which is attached to some of the body organs.)

Exhale by contracting organs upwards.

Inhale by contracting other muscles to increase body cavity, so organs settle and air is pulled in.



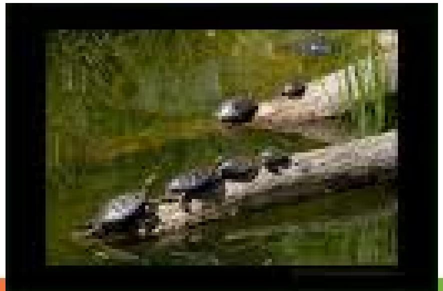
TEMPERATURE REGULATION

Need to warm up to speed digestion, growth and egg production.

Turtles bask on structures in ponds and creeks.

Higher temperatures can also kill algae and leeches on the turtle.

Sun also stimulates vitamin D production, which affects calcium deposition in bones and shell.



SOCIAL BEHAVIOR

Use tactile, visual, olfactory signals.

In pond turtles, after some initial courtship behavior, many males vibrate their claws against the sides of the female’s head. Allows visual recognition.

SOCIAL BEHAVIOR

Terrestrial turtles use grunts, moans and bellows, plus glandular secretions during courtship.

Territories may be marked with fecal pellets.

In fighting, turtles bite to the head and limbs, and ram and hook shells to flip over.

NESTING

Oviparous

Females excavate nest in sand or soil

Clutch from 5 to 100 eggs, depending on species.

Some laid in fall and wait in diapause until spring to finish development.

Individual sea turtle females may lay eggs every 2 to 3 years.

EGG DEVELOPMENT

Temperature, moisture, oxygen and CO_2 affect embryonic development.

Higher temp produced larger sex (generally female)

Males of crocodilians, lizards usually bigger.

3-4 degree span in temp can switch from one sex to the other.

Effect of global warming on reptiles?

Conservation strategies, need range of temps for nesting (marsh-cooler-female) vs.(levee-warmer- males) nesting for alligators.

NAVIGATION AND MIGRATION

Sea turtles navigate thousands of kilometers to find tiny coves on nesting beaches

Chemosensory cues, light, wave direction, magnetism

LEPIDOSAURIA

Lizards and snakes

Kinetic skull with extremely mobile joints (TOP jaw is hinged from skull.)

Overlapping scales

Tails may grow back partially if removed

Reduced limbs in many groups

Lizards have moveable eyelids and external ears while snakes do not

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Minden Pictures/Michael & Patricia Fogden

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(c) Gila monster

c: © Jim Merli/Visuals Unlimited

Sphenodon **– the Tuatara**

SQUAMATA – SNAKES AND LIZARDS

- **95% of all known living reptiles**
- **KINETIC skull**
- **Snakes are limbless and lack both pelvic and pectoral girdles**

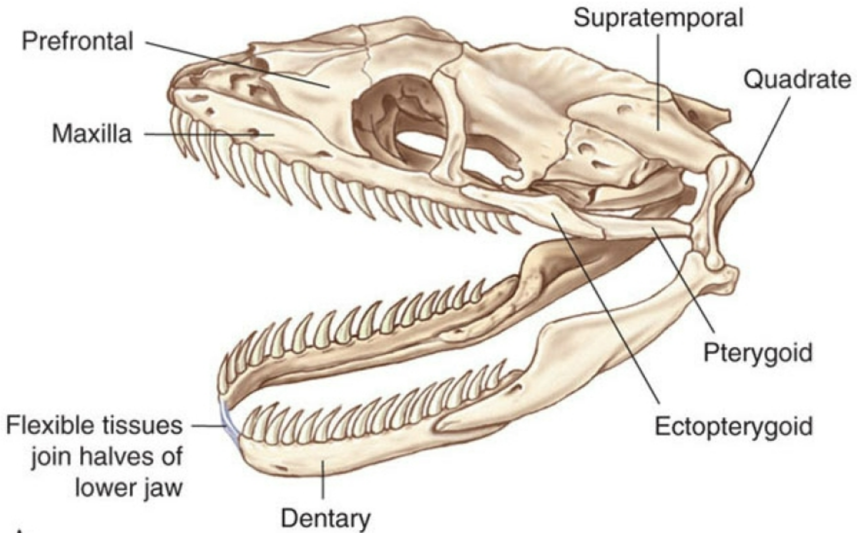
2 MAJOR LINEAGES OF SQUAMATES

Iguania

- Terrestrial and arboreal lizards (many herbivorous), including iguanas, chameleons, spiny lizards and anoles

Scleroglossa

- Geckos, skinks, amphisbaenians (worm lizards), legless lizards, alligator lizards, Gila monster, monitor lizards (3 min) and snakes.



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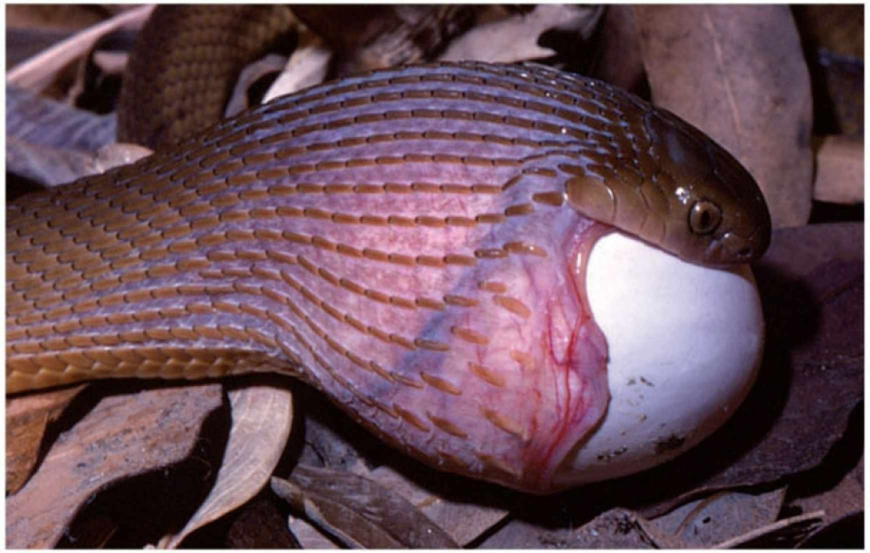

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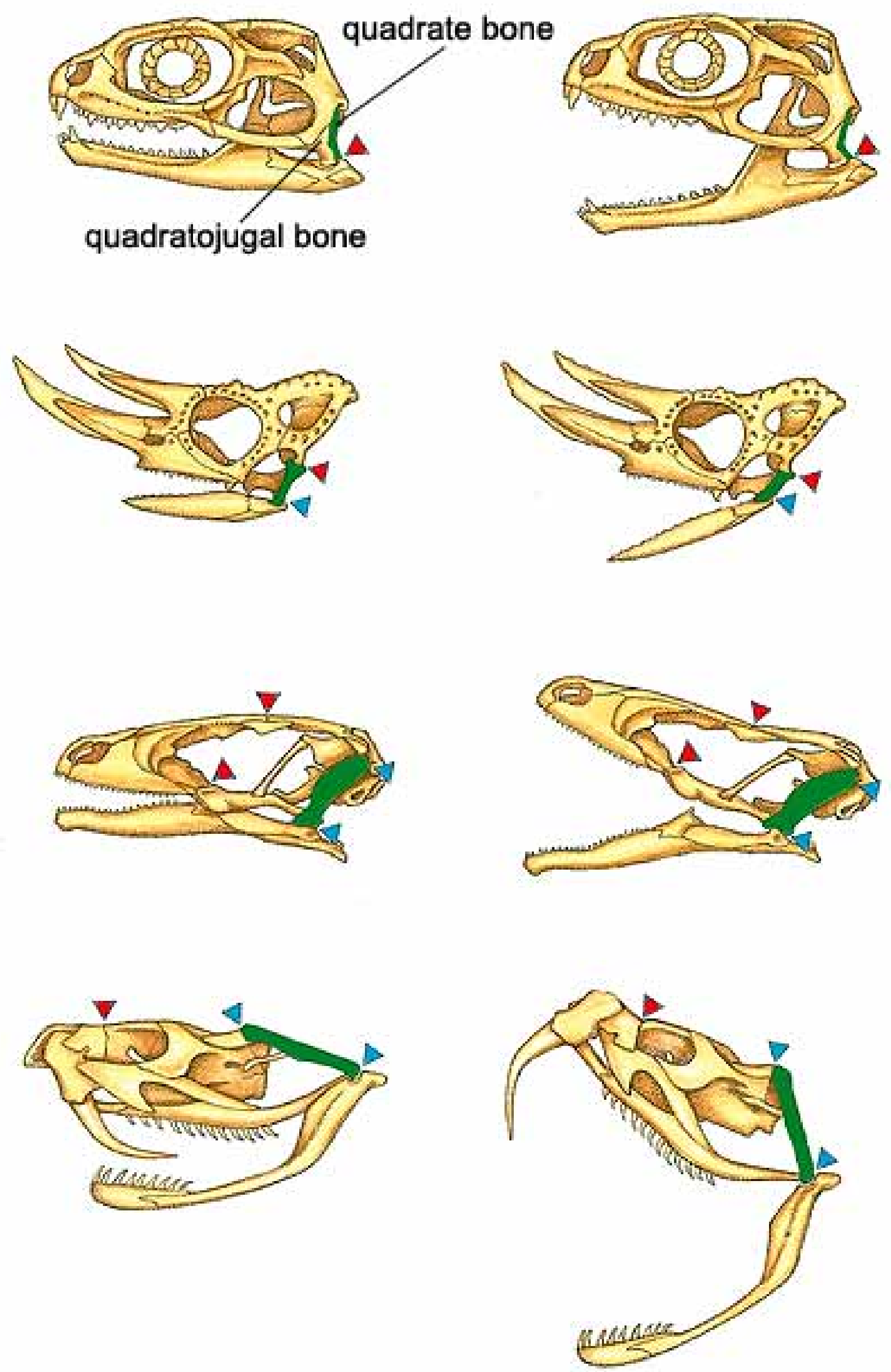
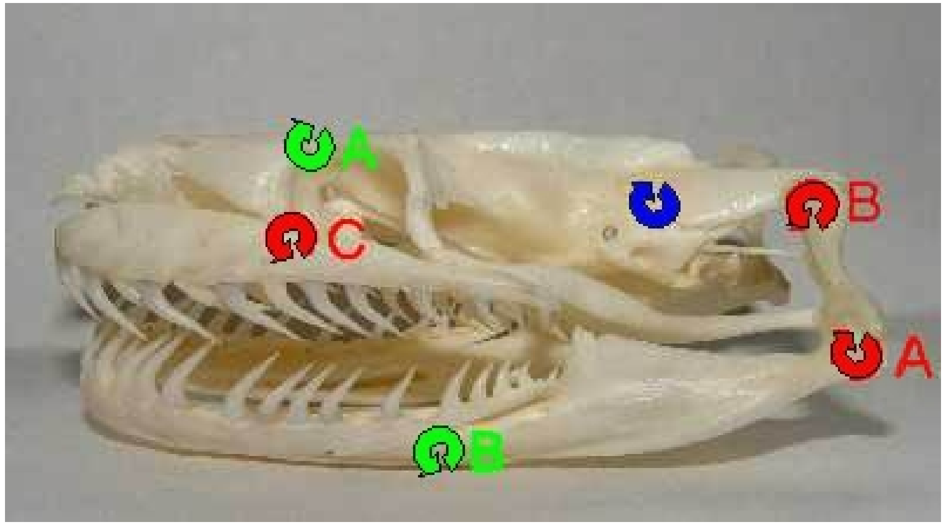
B: © Austin J. Stevens/Animals Animals/Earth Scenes

Egg eating snake


quadrate bone
quadratojugal bone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Western U.S. snakes and lizards

SNAKE-LIKE LIZARDS

Many legless or nearly legless species of lizards. Evolved independently more than 60 times.

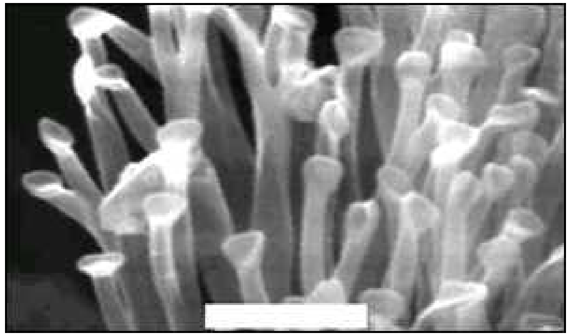
Amphisbaenians are fossorial (burrowing) lizards. Skin is not attached to the trunk, so their bodies slide back and forth within the tube of their skin. Can move forward and backward equally.

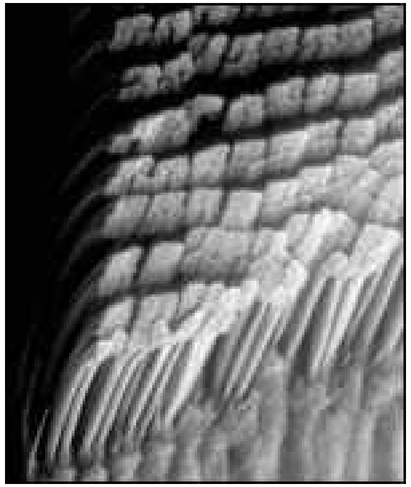
GECKO FEET

Can stick to smooth surfaces, even
upside down. No adhesive secretions,
no friction, no suction.

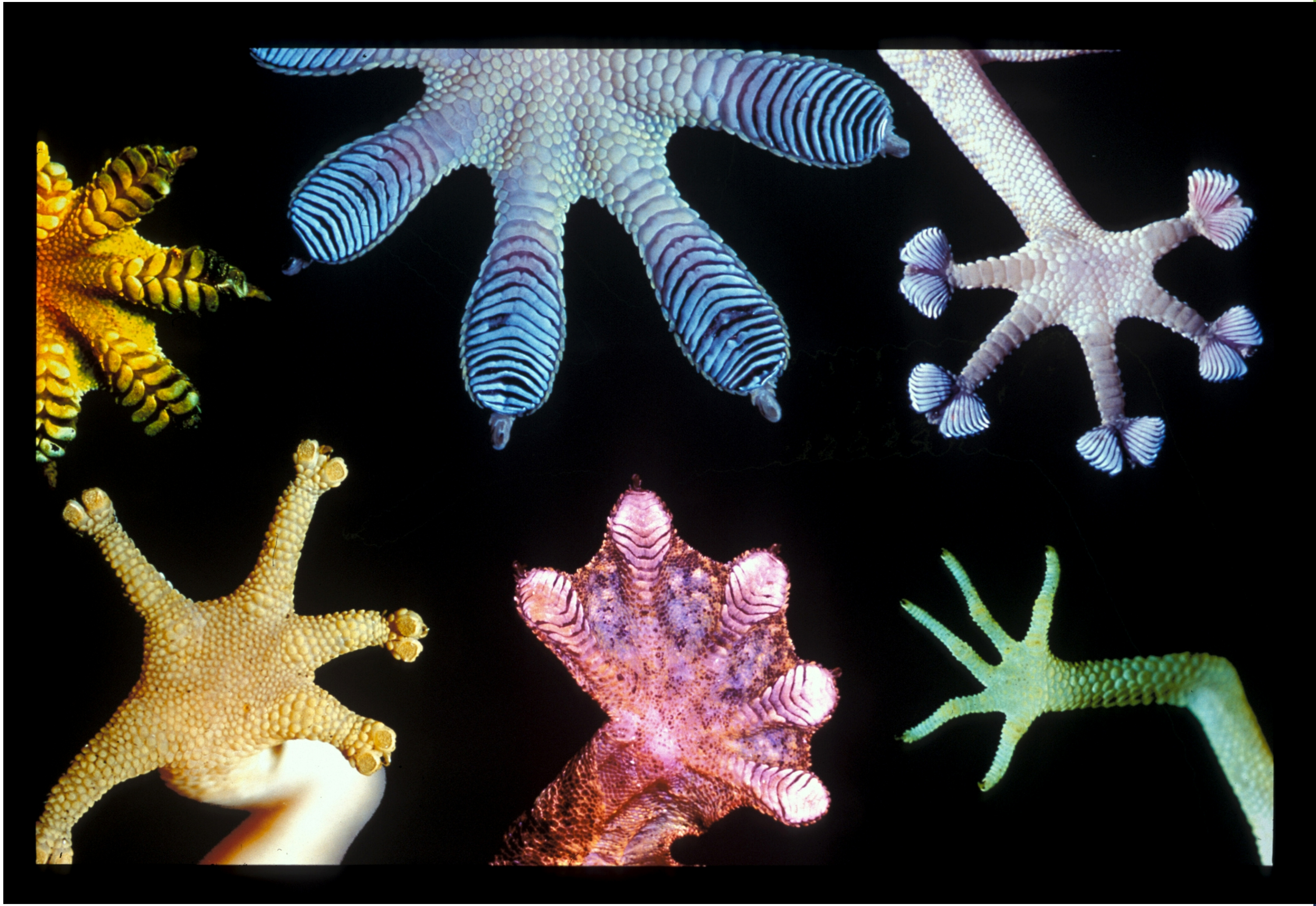
Tiny hairs on feet produce electromagnetic attractions on a surface = van der Waals forces.

2 million tiny hairs on a toe. Each hair divided into 100,000's of structures called Spatulae.

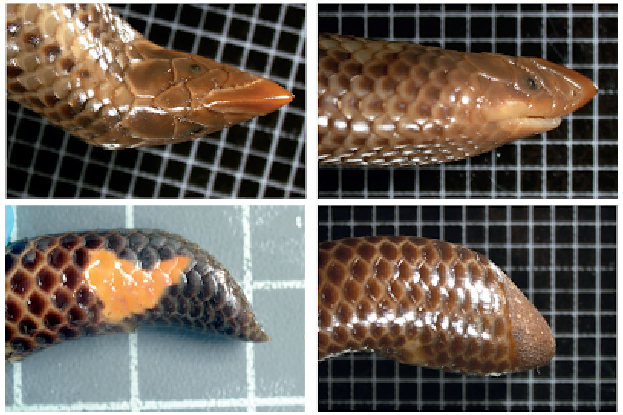




GECKO FEET



GECKO FEET



SNAKES

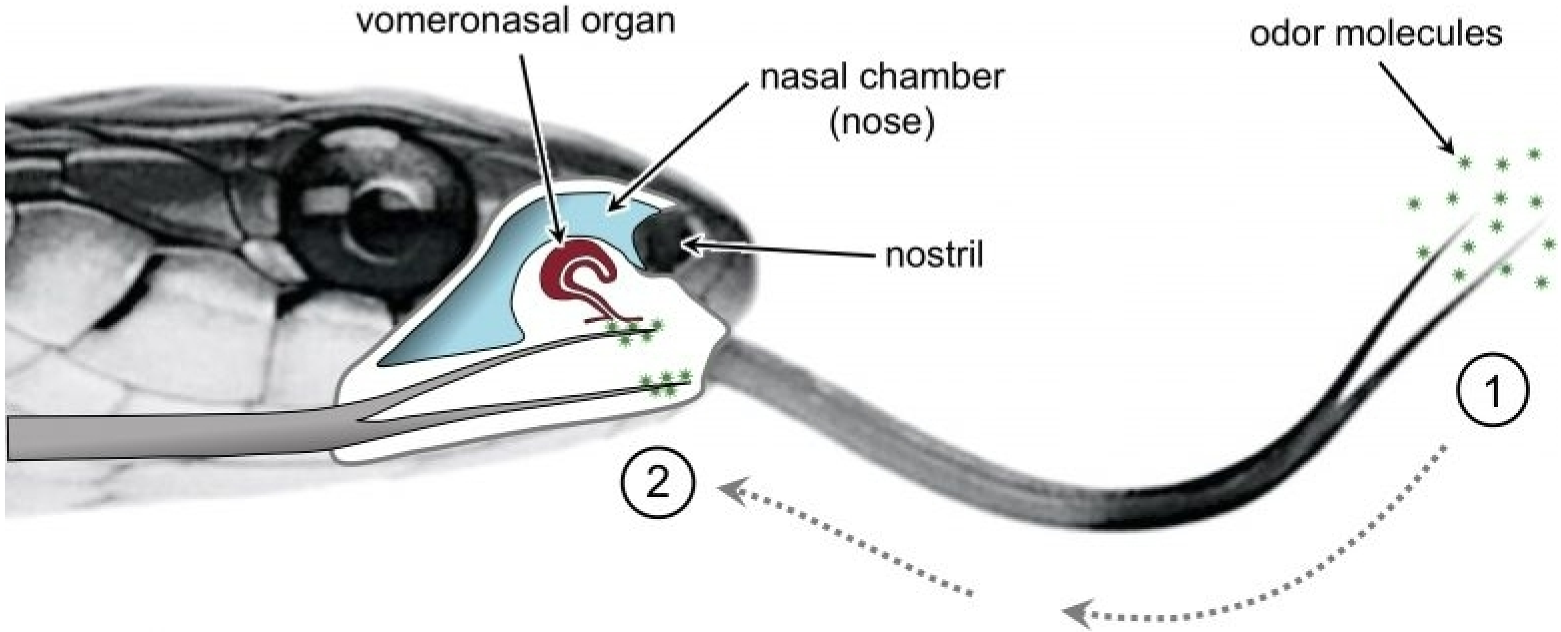
2900 species, 10 cm to 10 meters.

Some burrow, some are tree living.

Forked tongues are used for chemoreception.

Arboreal snakes have large eyes, fossorial ones have small eyes.

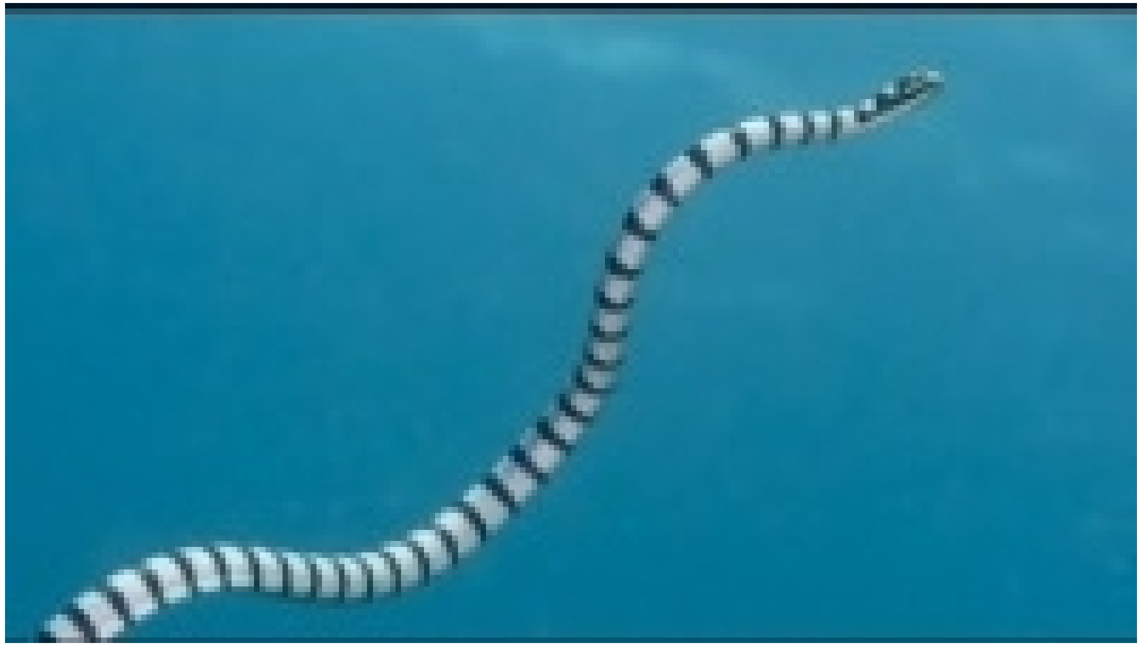
SNAKE TONGUE ODOR SENSOR



https://scitechdaily.com/smelling-in-stereo-the-real-reason-snakes-have-flicking-forked-tongues/

SEA SNAKES

Sea snakes have tails modified for swimming, valves on the nostrils, elongated lungs used for buoyancy.



SNAKES

Less than 20% of snakes are venomous (but in Australia 4 to 1 venomous to nonvenomous).

Pit vipers have heat sensing pits. Fangs erected as mouth opens.

Pythons and boas have heat sensing pit organs. Can detect 0.003°C temp differences

Rattlesnakes, copperheads and cottonmouths in North America are pit vipers.

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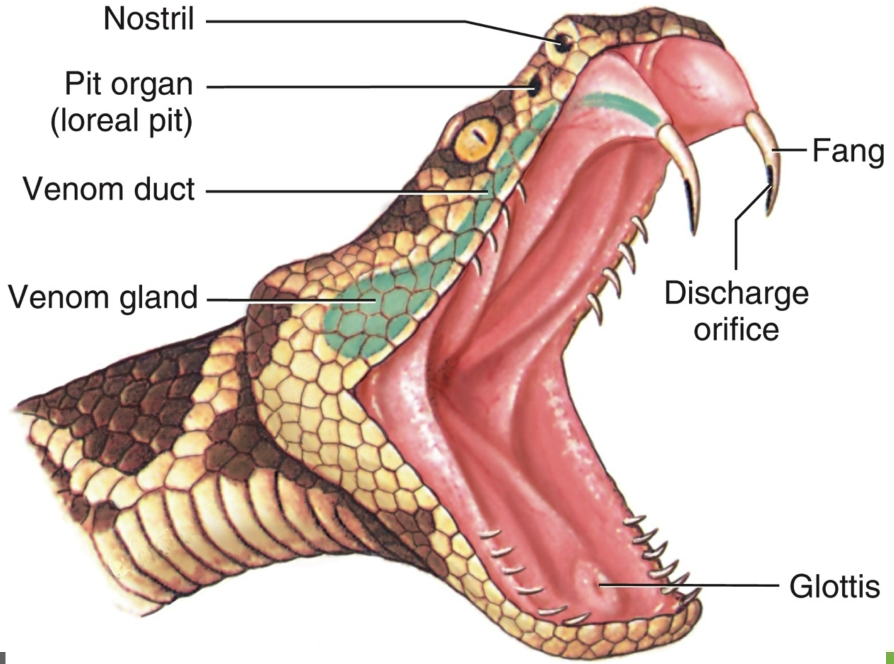
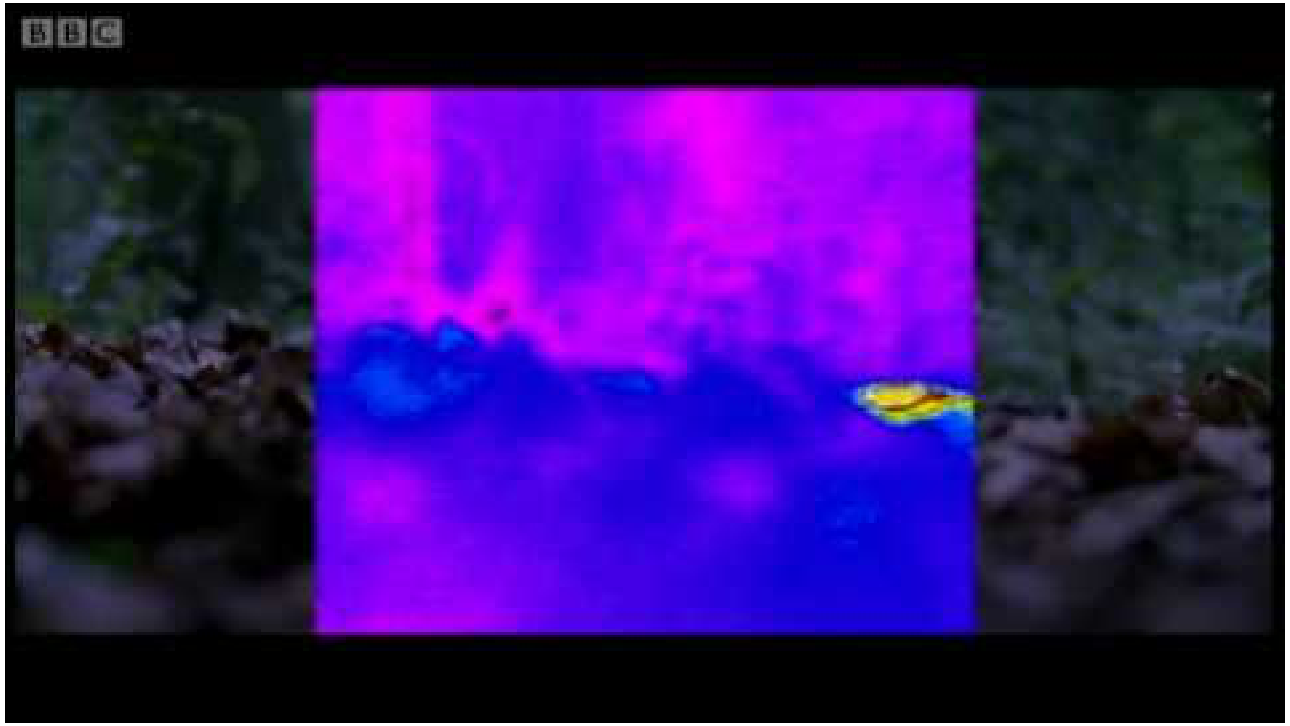
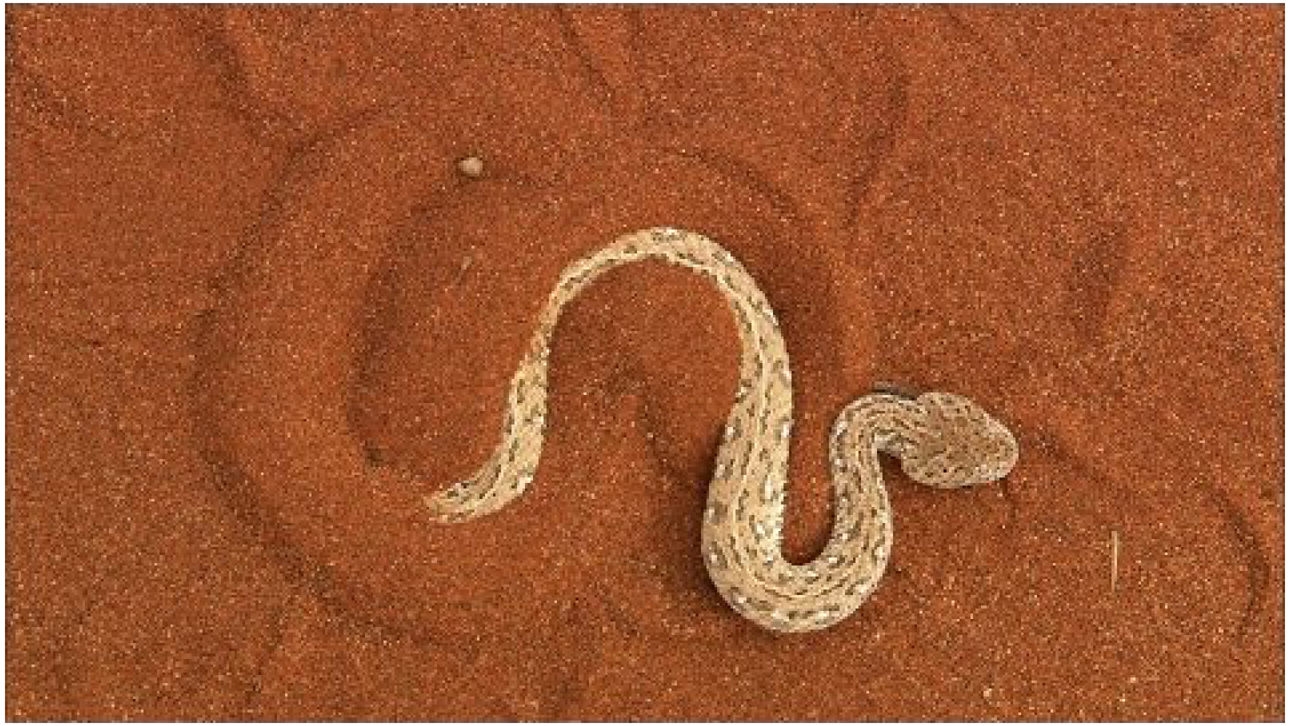


Heat sensing pit vipers



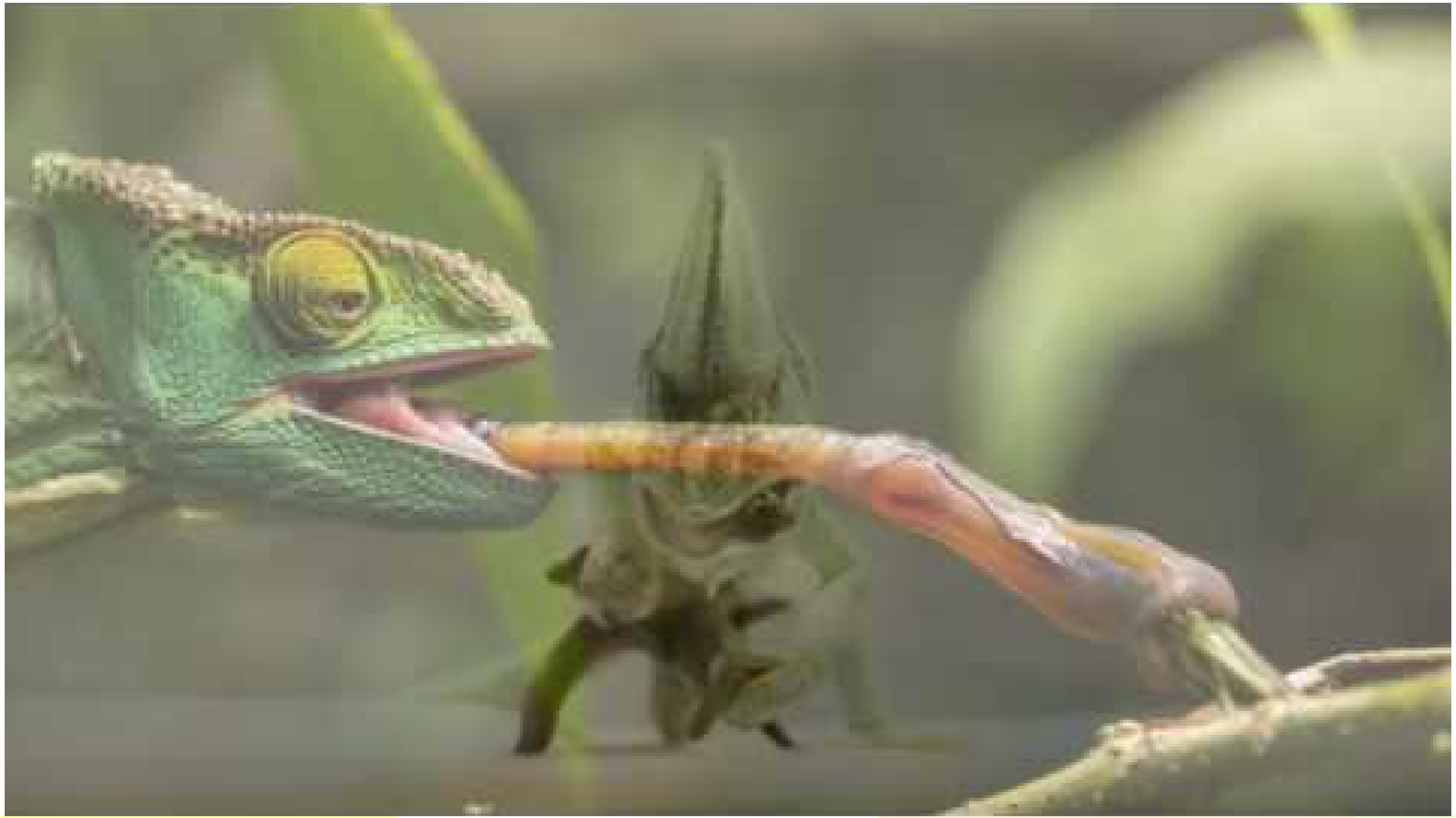
Sidewinder movement



Komodo dragon

LIZARD FEEDING

Chameleons have a specialized tongue and hyoid apparatus, and tongue can shoot out more than the body’s length to capture insects.



Chameleon feeding

CLADE ARCHOSAURIA, CLASS CROCODILIA

Crocodiles and alligators

Essentially unchanged for 200 million years

4 chambered heart

Teeth in sockets

Care for young

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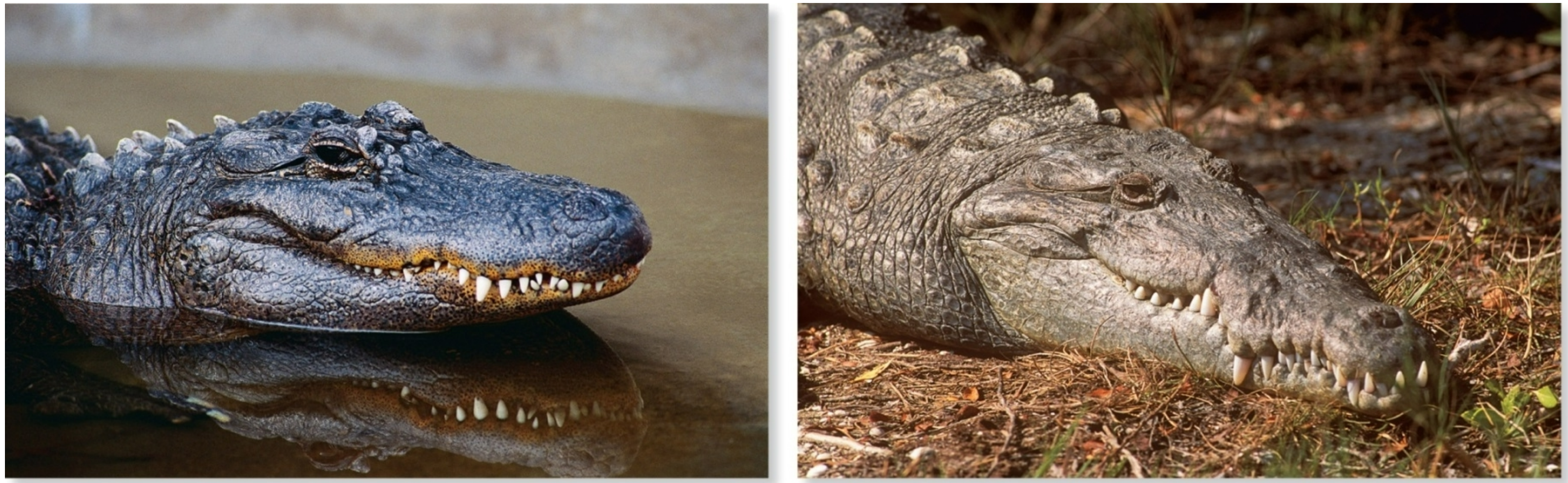
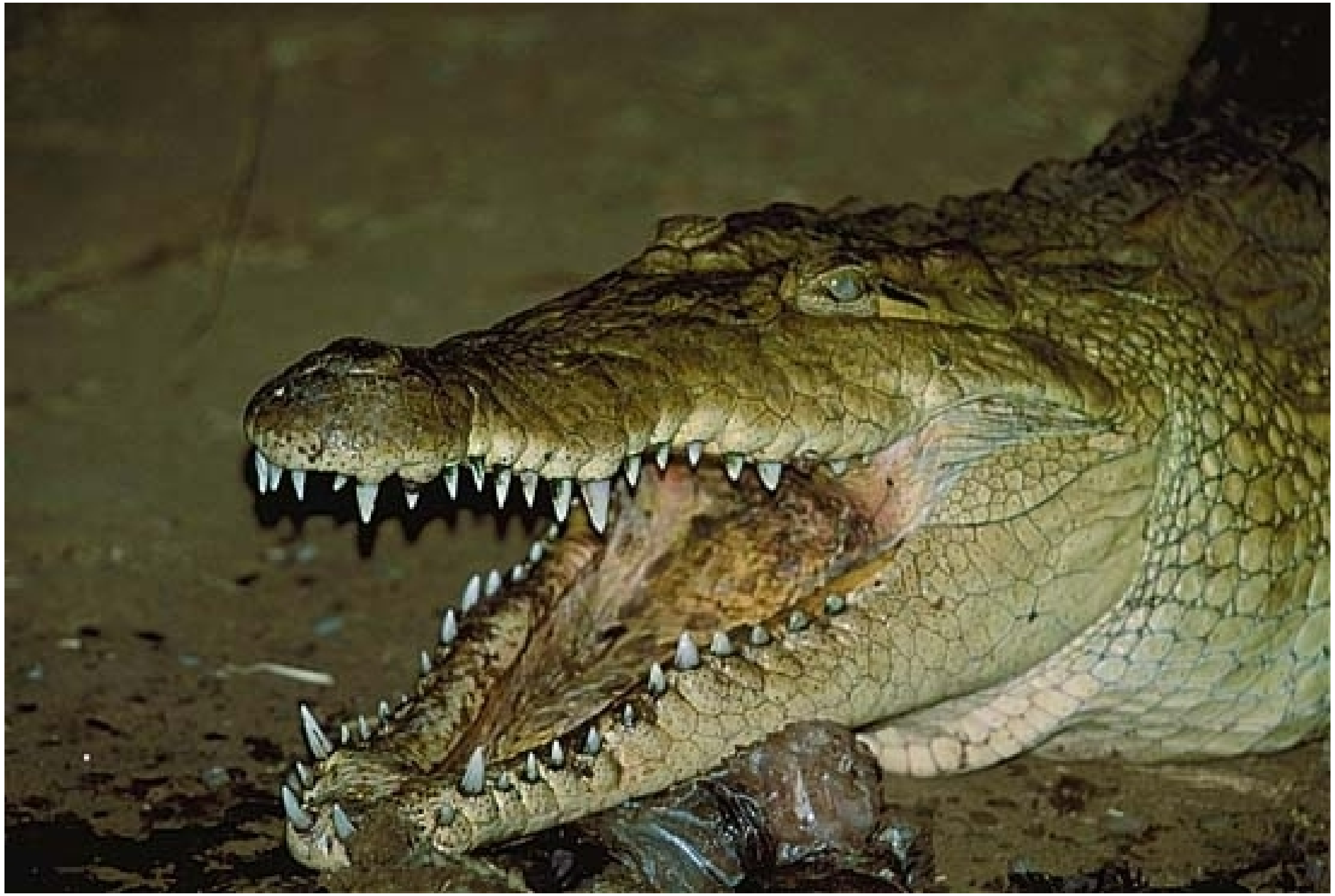


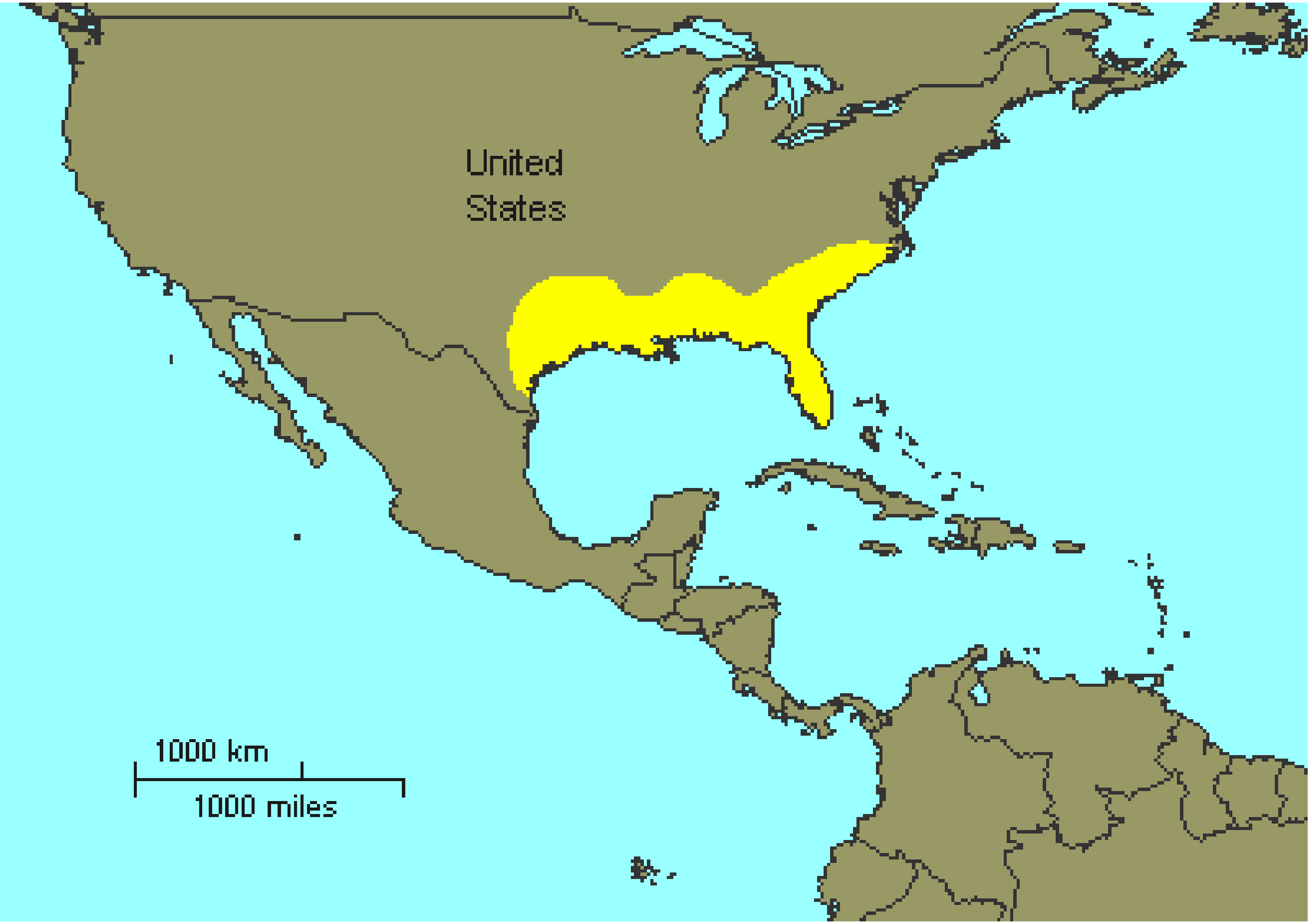
(a) American alligator

(b) American crocodile

a: © Warren Jacobi/Corbis RF; b: © J. & C. Sohns/Animals Animals



Nile crocodile



Distribution of *Alligator mississippiensis*

Characteristics of Birds (in addition to the reptilian ones)

- **Forelimbs highly modified as wings, usually for flying**
- **Feathers instead of scales in most places - wind resistance and insulation**
- **Usually FOUR toes, but reductions in some**
- **Endothermic**
- **4-chambered heart**
- **Bony skeleton with air cavities (light weight) and air sacs (respiration)**
- **Females with only single (left) ovary and oviduct, no urinary bladder**
- **HARD-shelled eggs with much yolk: extensive parental care**
- **NO TEETH: hard beak with enormous variation in form**
- **Fast digestion of food**

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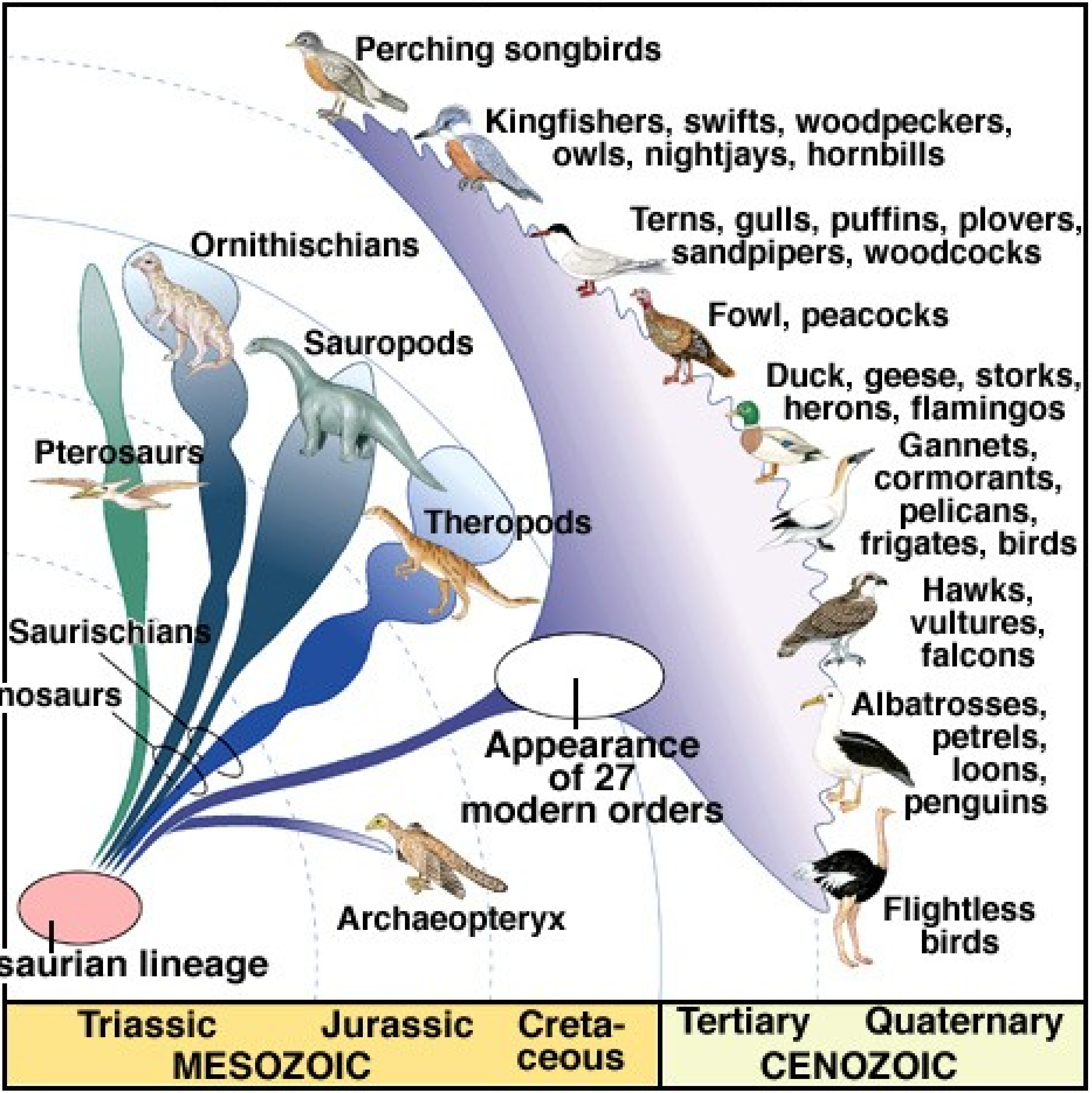
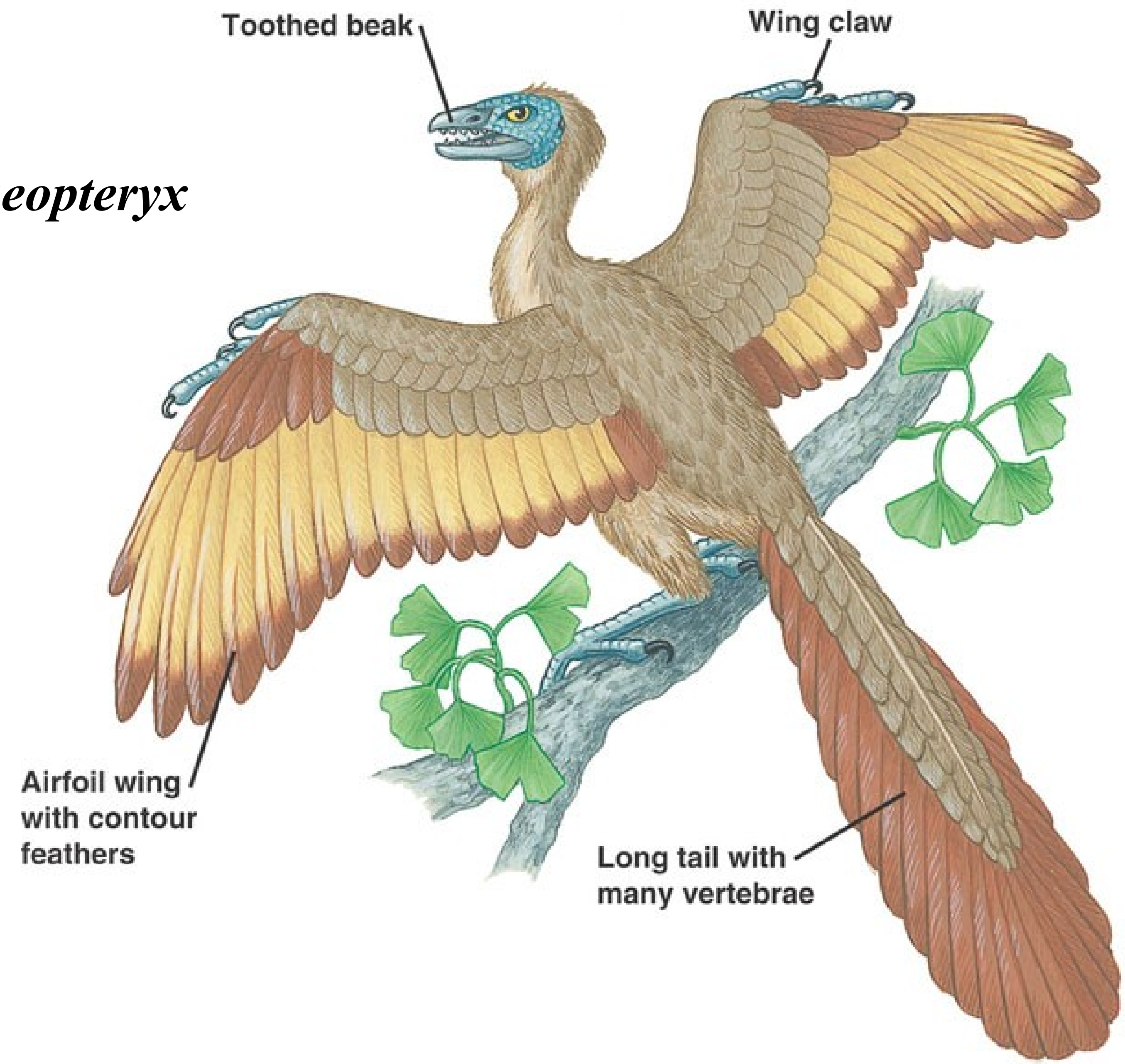
Evolution of modern birds


Perching songbirds
Kingfishers, swifts, woodpeckers, owls, nightjays, hornbills
Terns, gulls, puffins, plovers, sandpipers, woodcocks
Fowl, peacocks
Duck, geese, storks, herons, flamingos
Gannets, cormorants, pelicans, frigates, birds
Hawks, vultures, falcons
Albatrosses, petrels, loons, penguins
Flightless birds
Ornithischians
Sauropods
Pterosaurs
Theropods
Saurischians
Dinosaurs
Appearance of 27 modern orders
Archaeopteryx
Archosaurian lineage
Triassic
Jurassic
Creta-ceous
MESOZOIC
Tertiary
Quaternary
CENOZOIC

Archaeopteryx


Toothed beak
Wing claw
Airfoil wing with contour feathers
Long tail with many vertebrae

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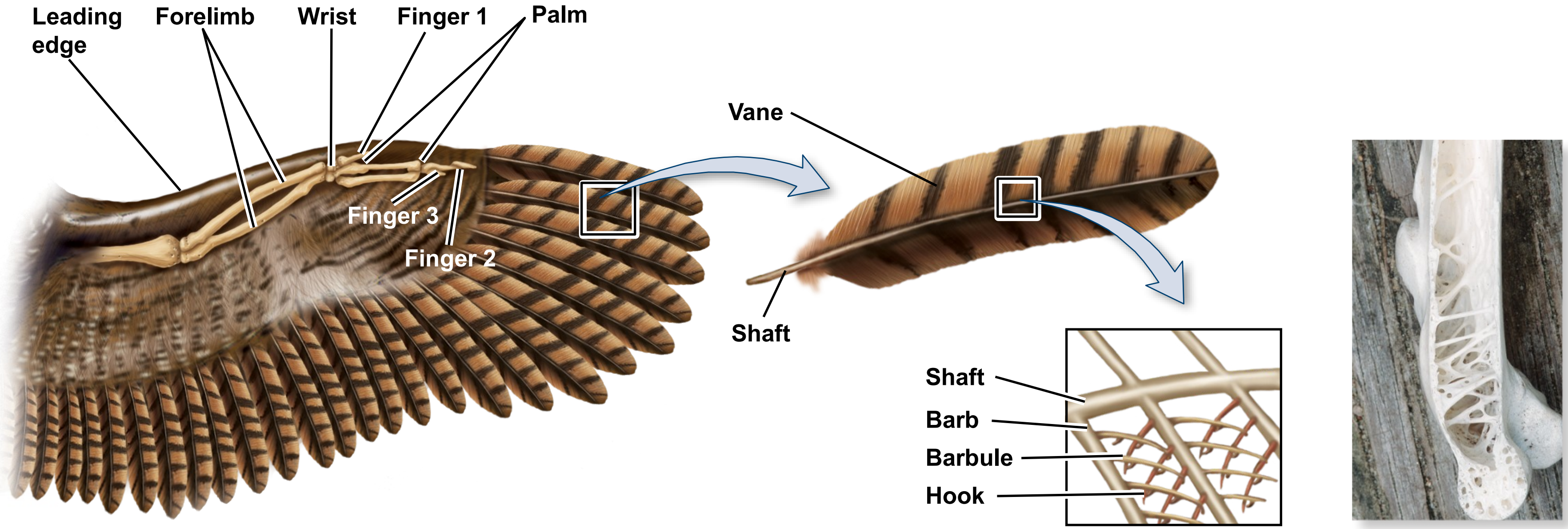

(a) Wing

(b) Feather structure

(c) Pelicanbone (*Pelicanus occidentalis*)

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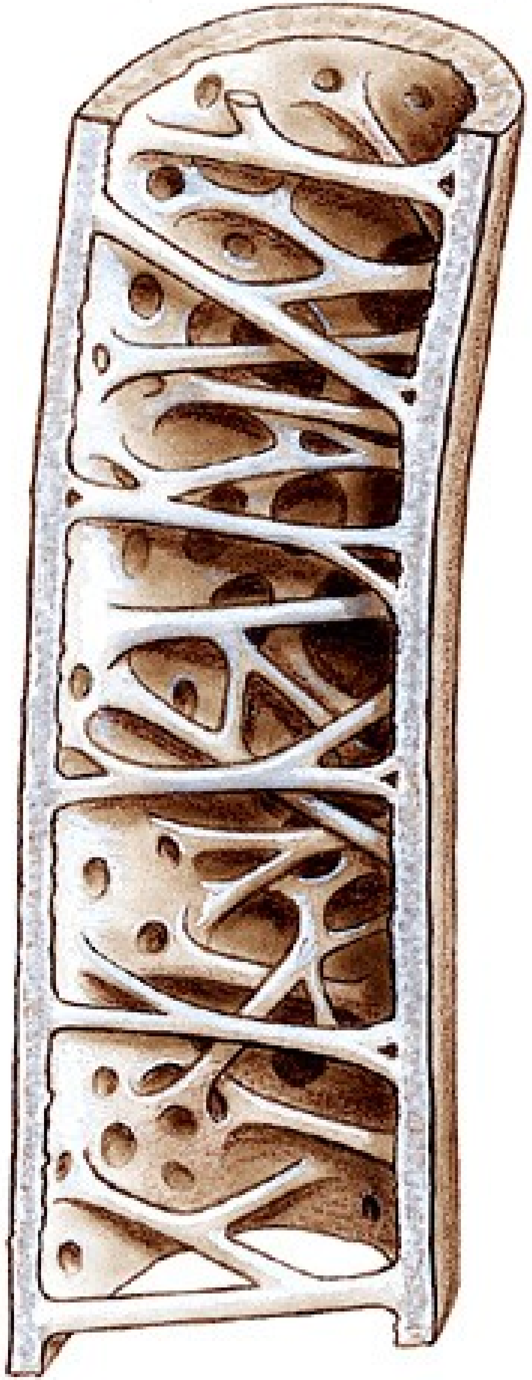
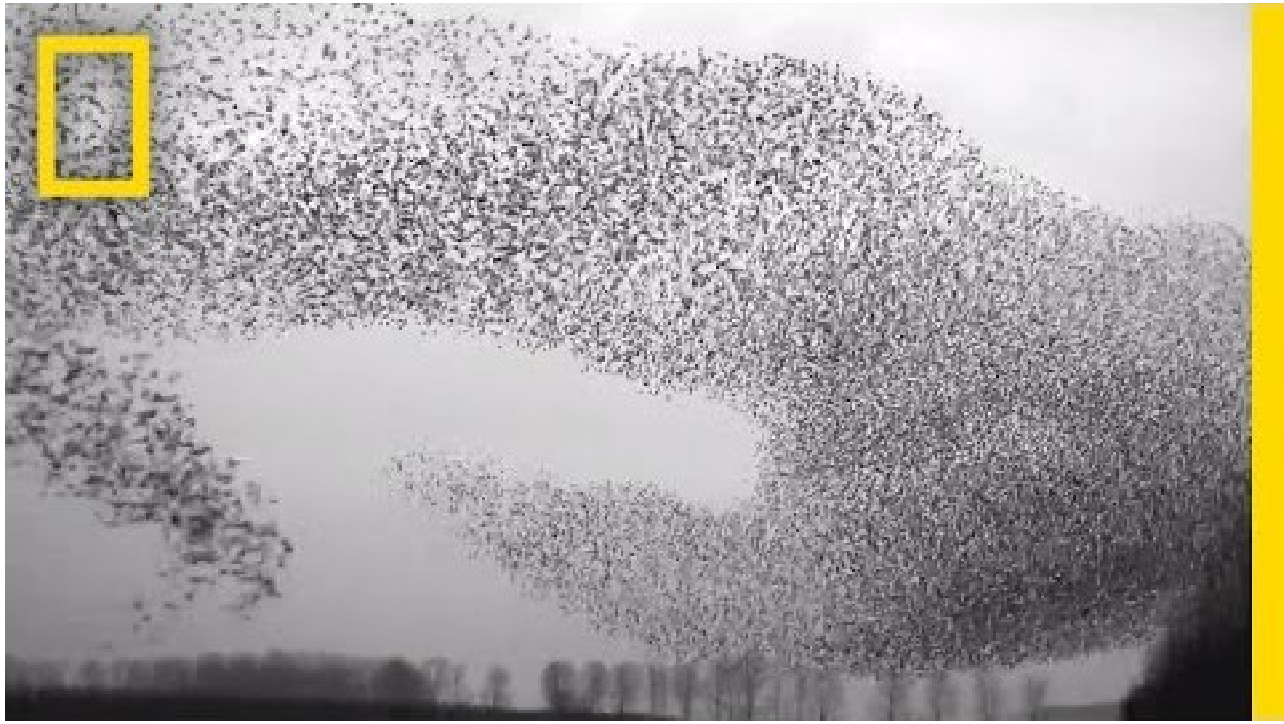
Hollow wing bone of a songbird



Starling murmuration



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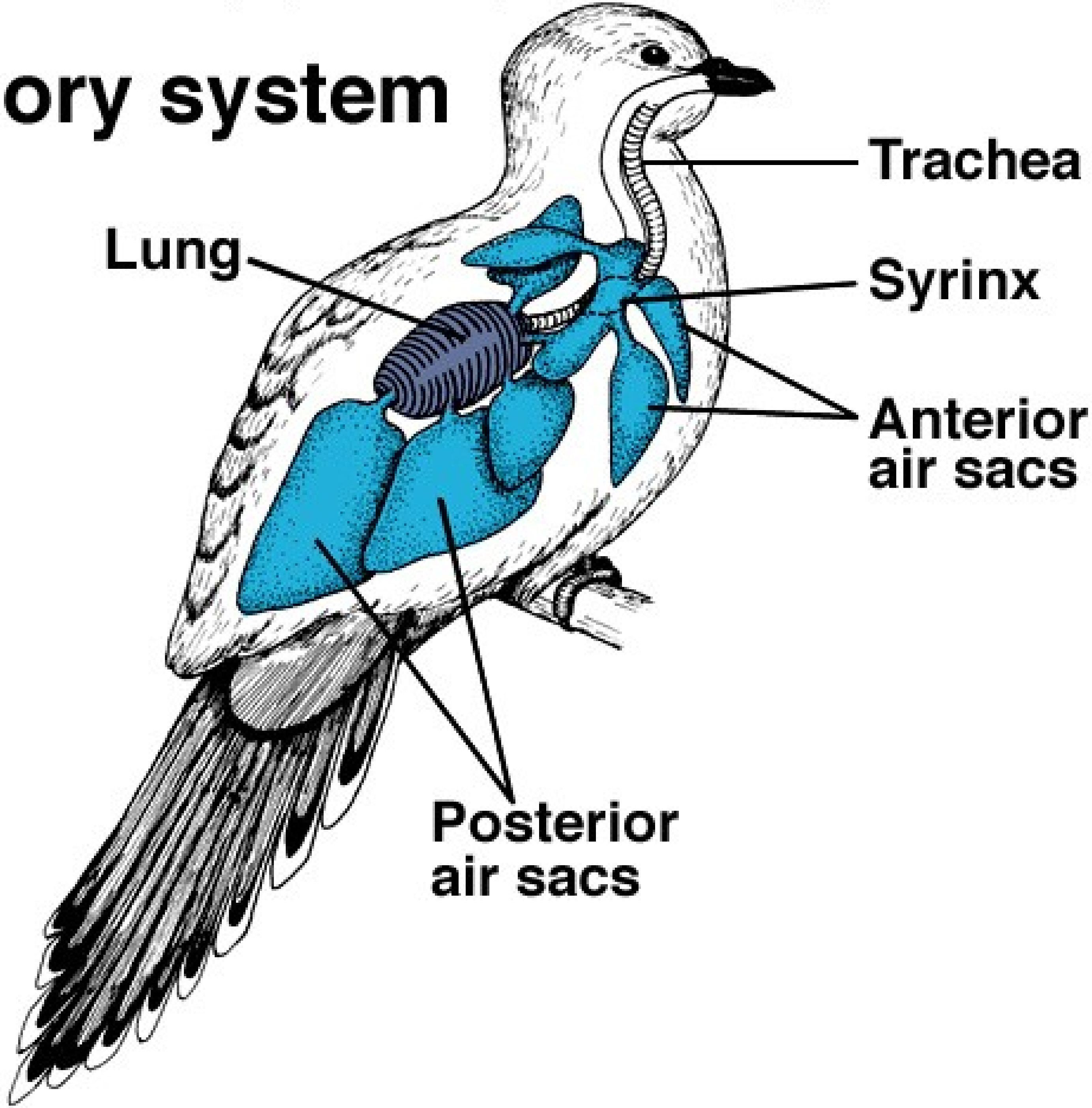
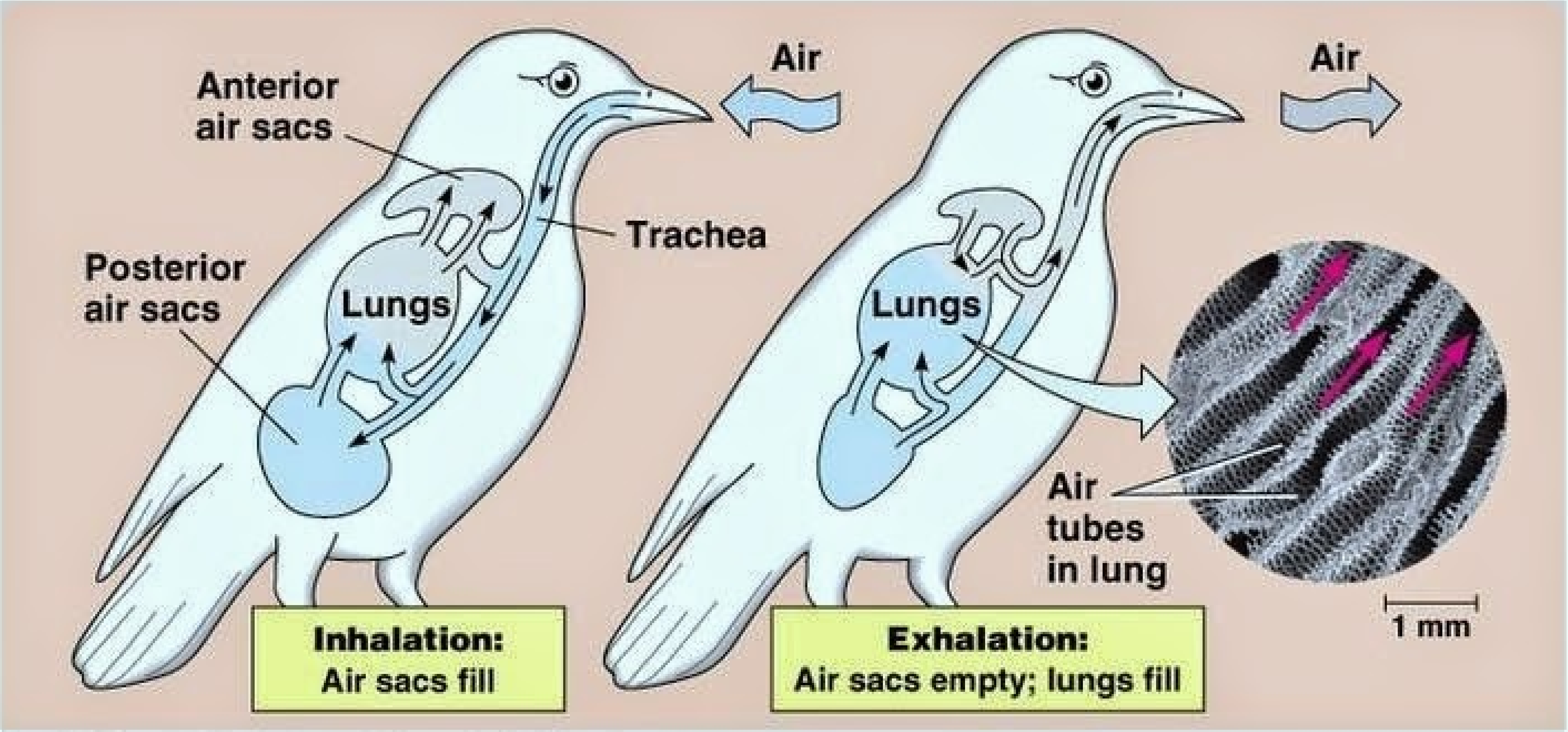
Respiratory system of a bird





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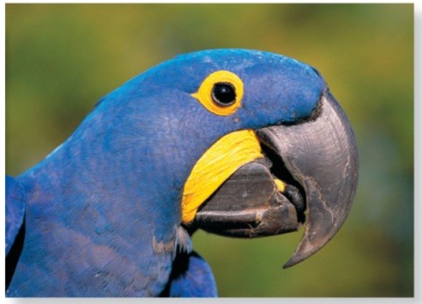
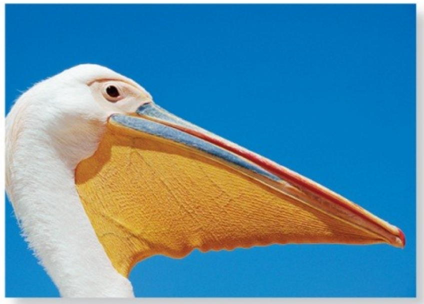
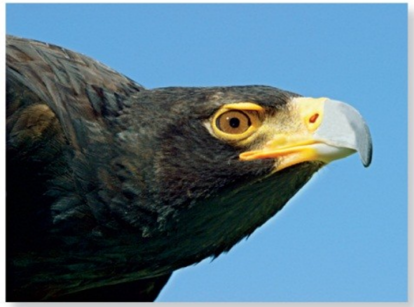


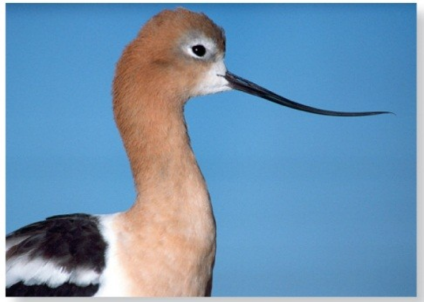
(a) Cracking beak



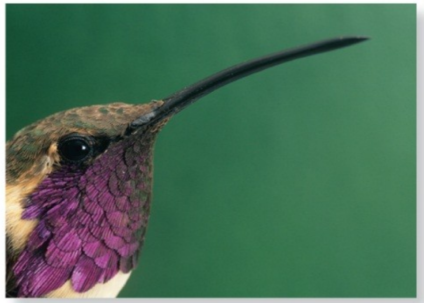
(b) Scooping beak



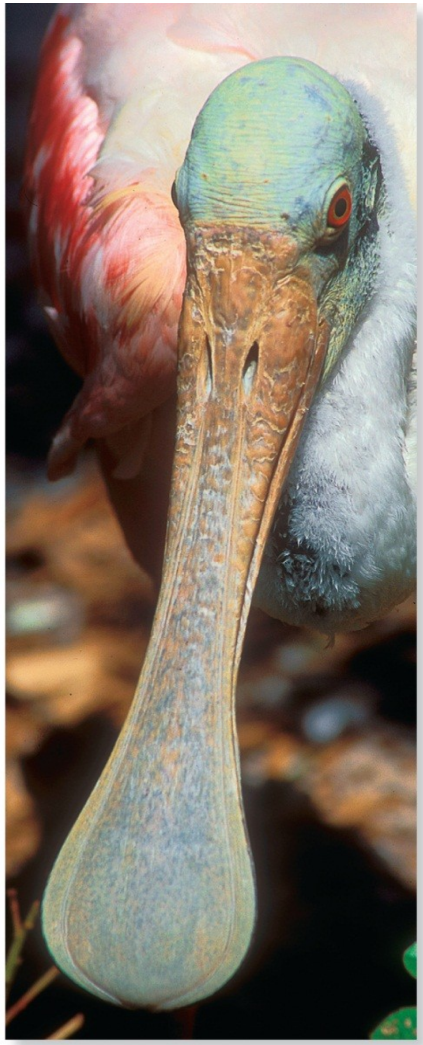
(c) Tearing beak



(d) Probing beak



(e) Nectar-feeding beak



(f) Sieving beak

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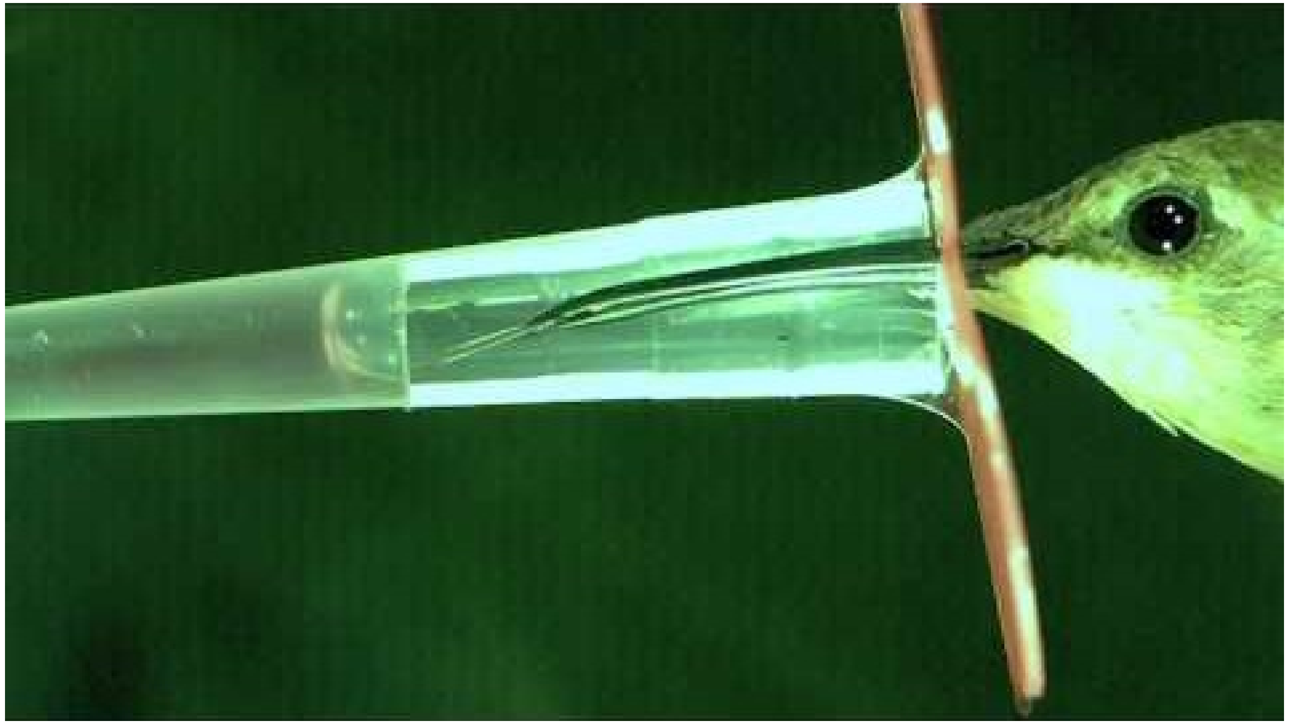
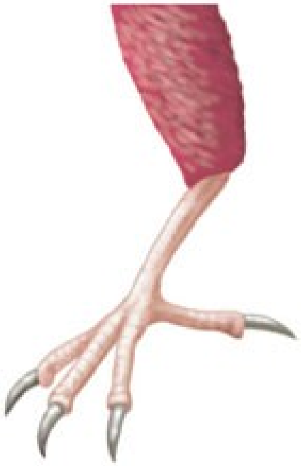
d: © Brand X Pictures/PunchStock RF; e: © Rick& Nora Bowers/Visuals Unlimited; f: ©MervynRees/Alamy

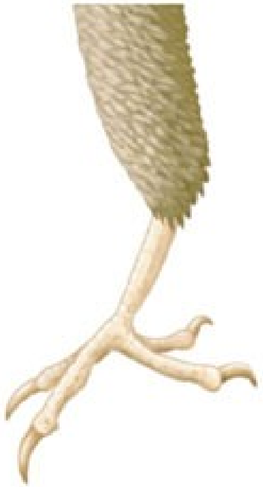
Kingfisher Dive

Hummingbird tongue

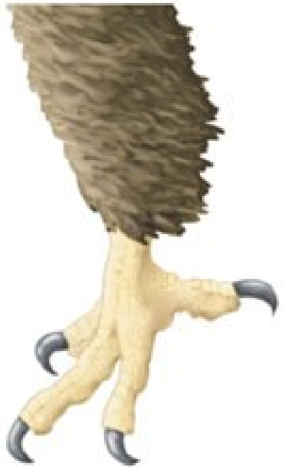




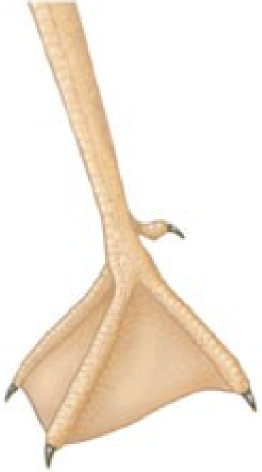
Perching bird
(such as a
cardinal)



Grasping bird
(such as a
woodpecker)



Raptor
(such as a
bald eagle)



Swimming bird
(such as a
duck)

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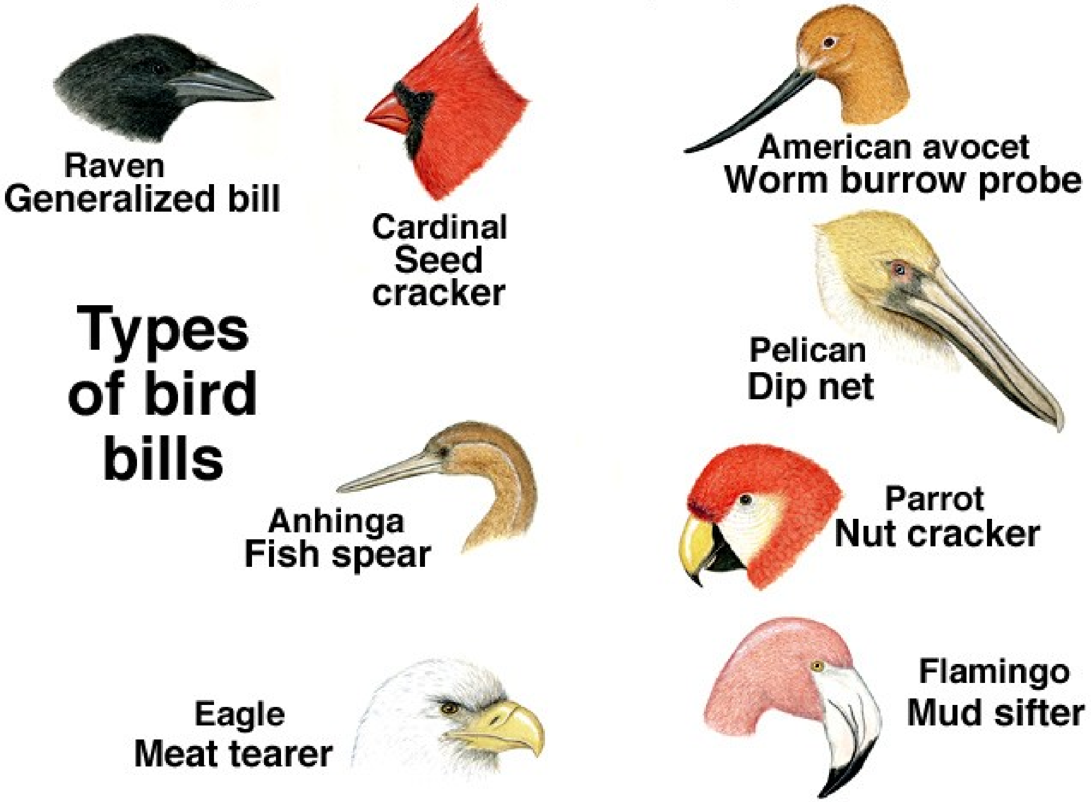
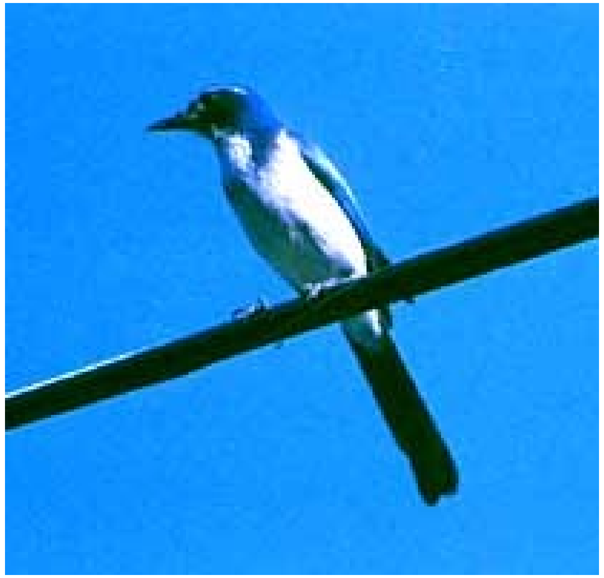
Types of bird bills

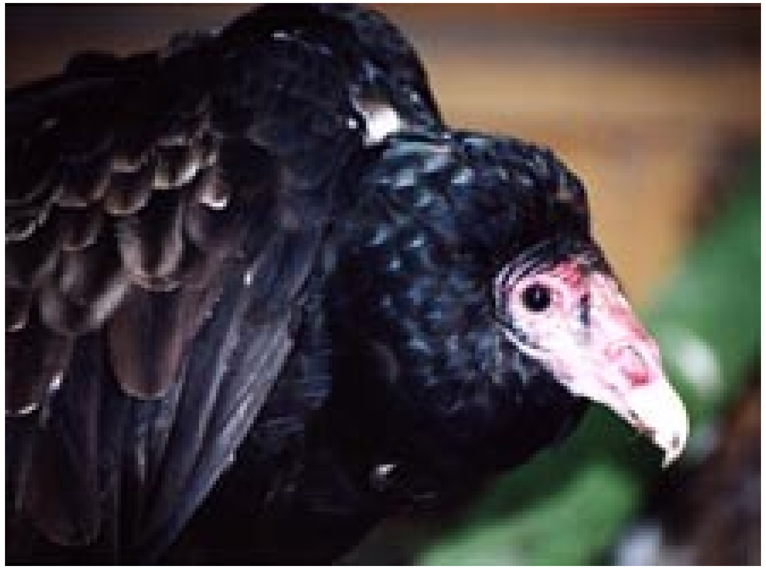


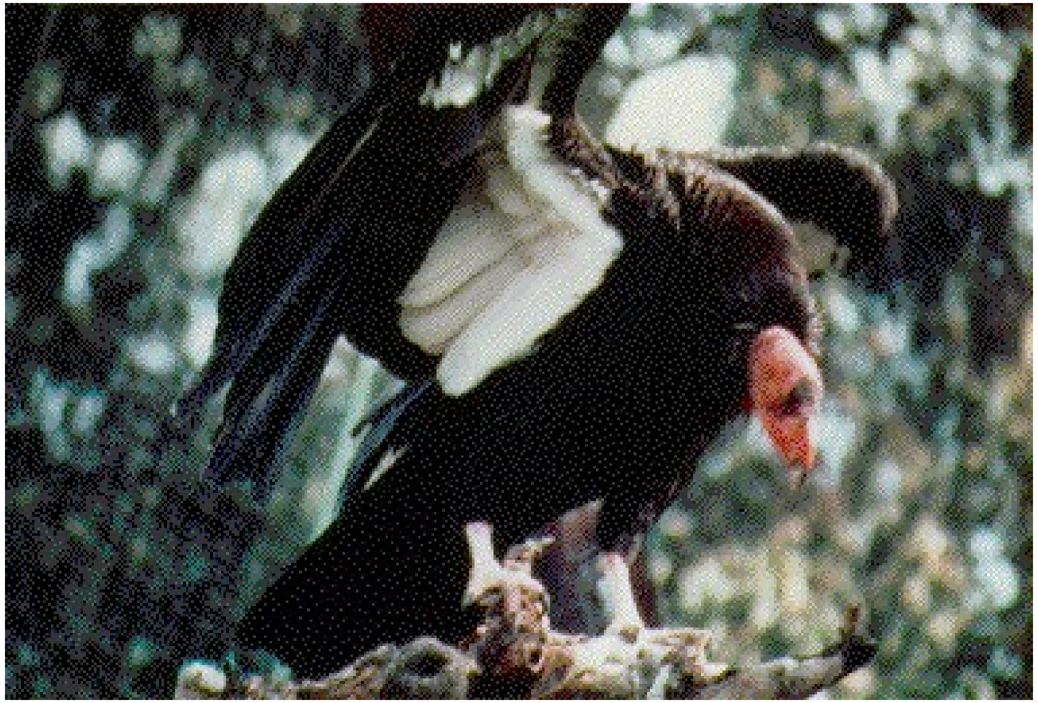
Tree nesting wood ducks

Red-tailed Hawk

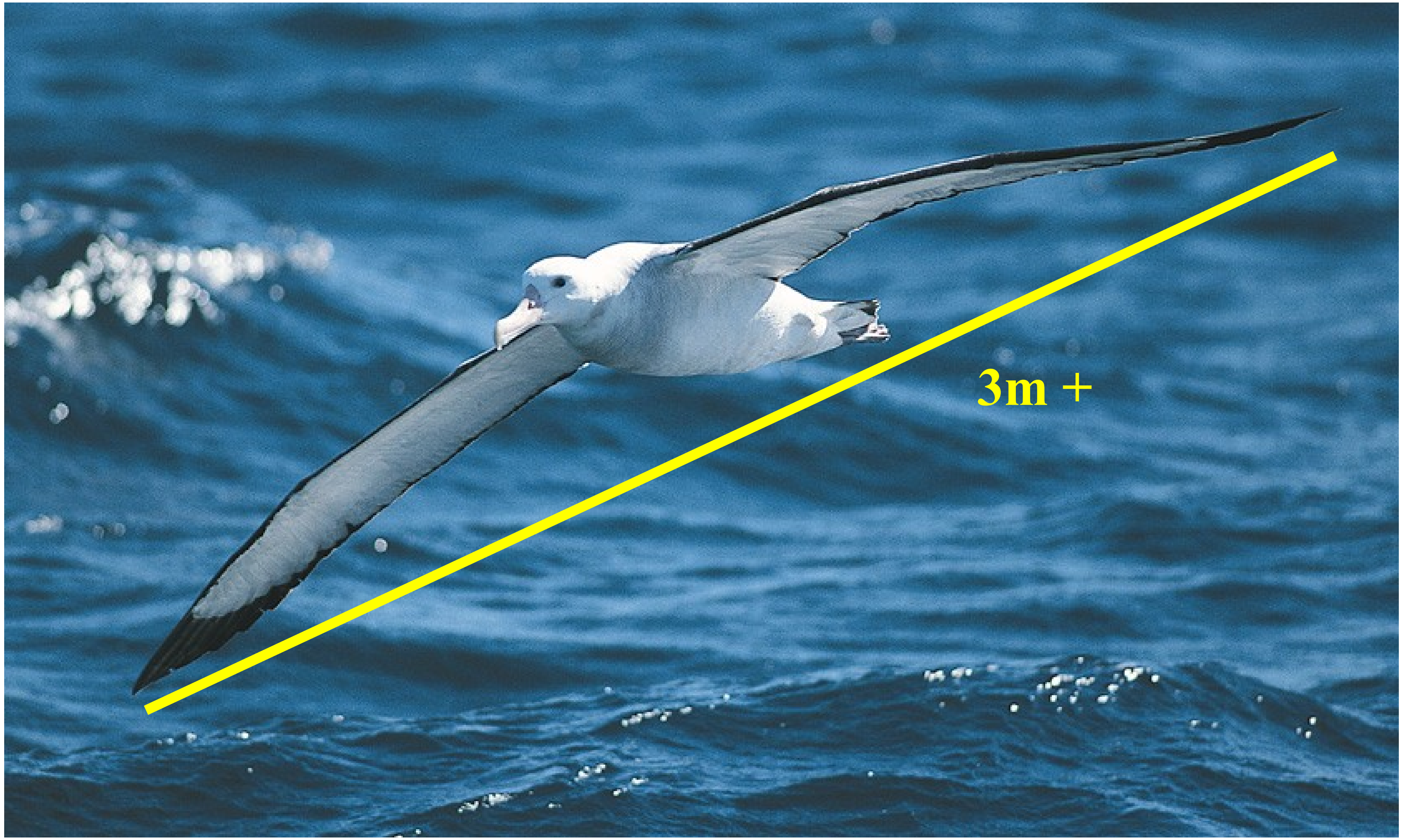
Kingfisher dive





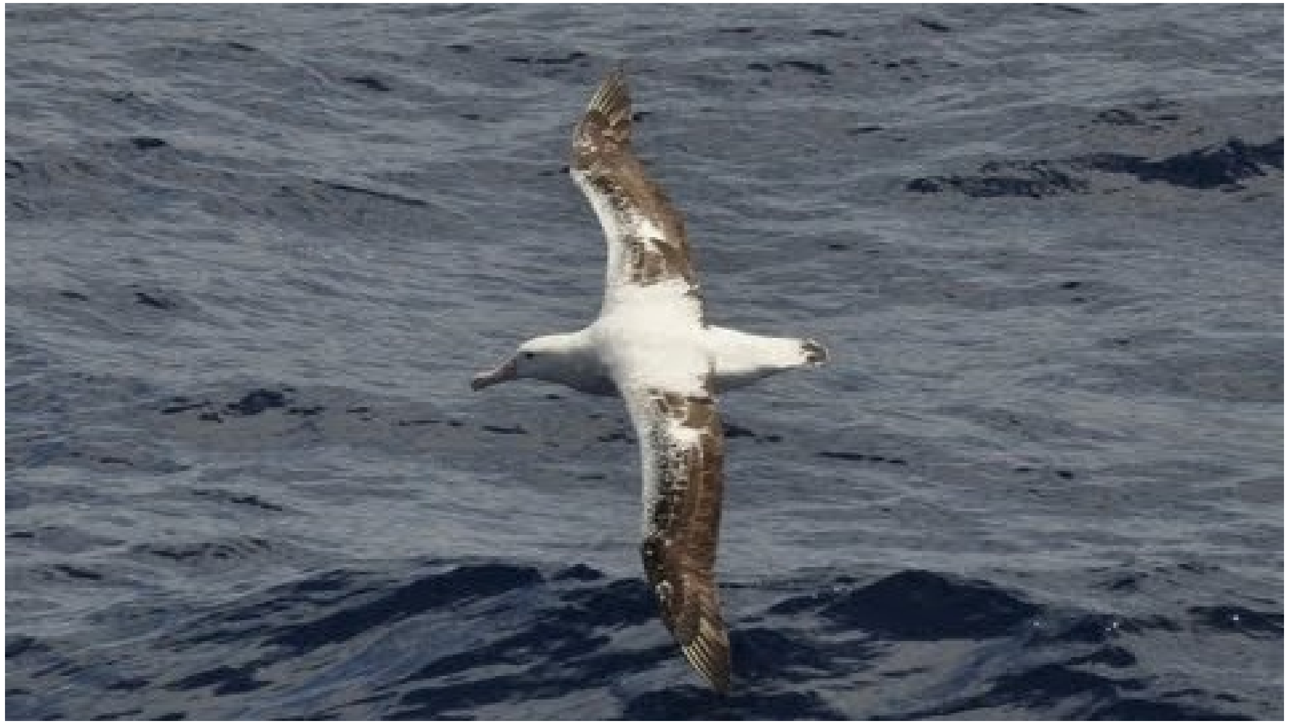


Scrub Jay, Turkey vulture, California condor, clockwise from top left



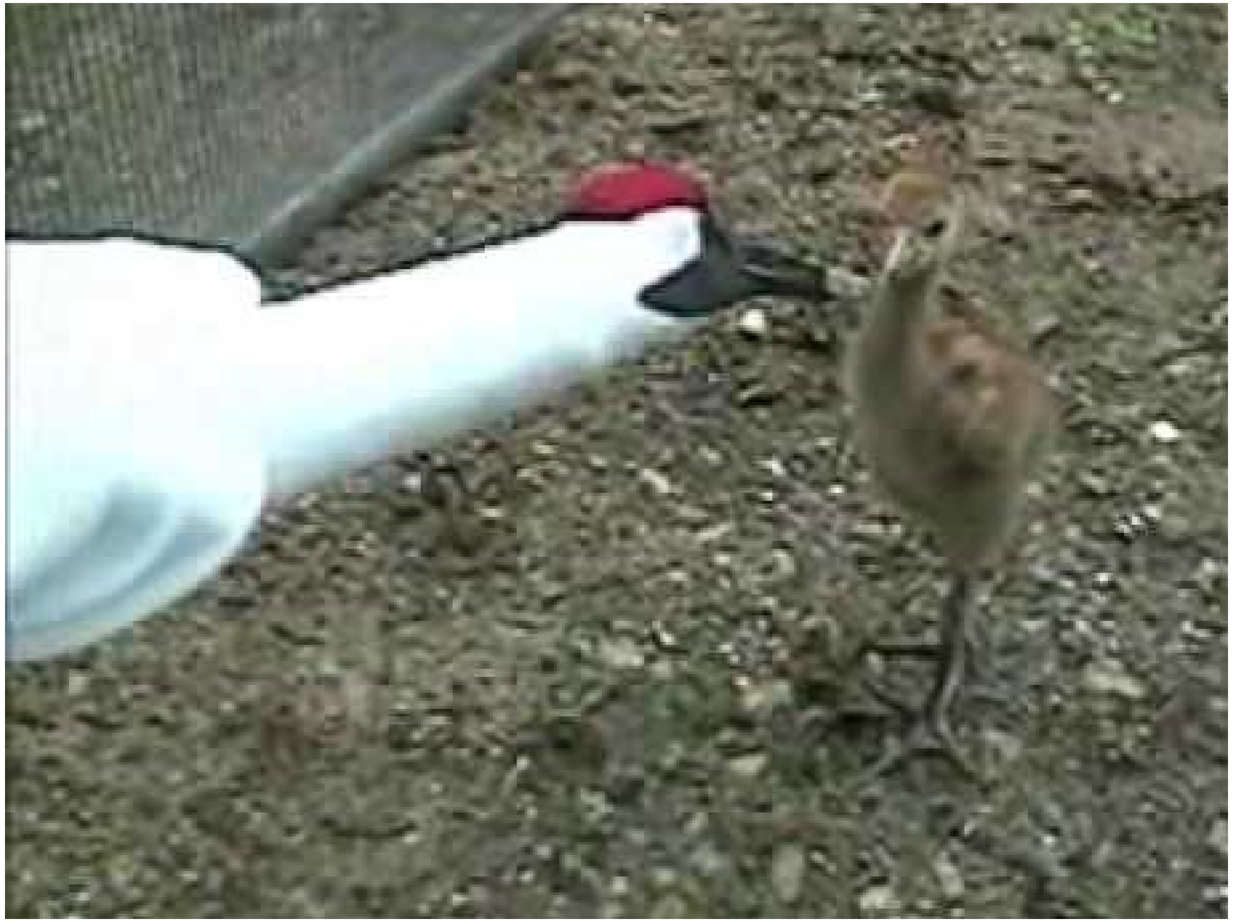
Wandering albatross Earthflight

Wandering Albatross

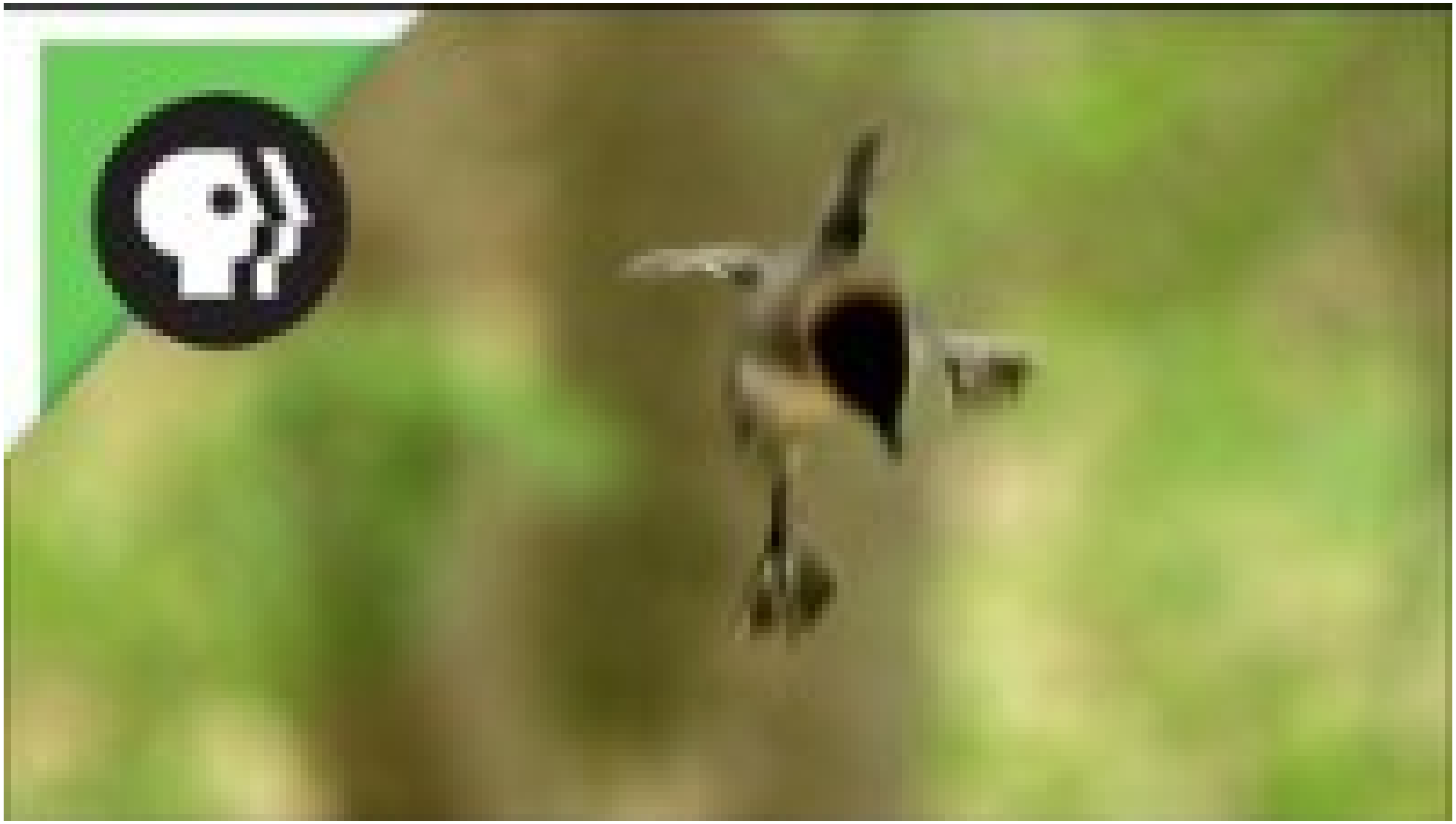


Earthflight (Winged Planet) highlights

Operation Migration: Whooping Cranes



All about hummingbirds. 4:10 backwards flight in slow motion



Mammals:
Milk-Producing Amniotes

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Evolved from amniote ancestors earlier than birds (150 mya)

Appeared about 225 mya

After dinosaur extinction, mammals flourished

Range of sizes and body forms unmatched

~ 4,700 spp.

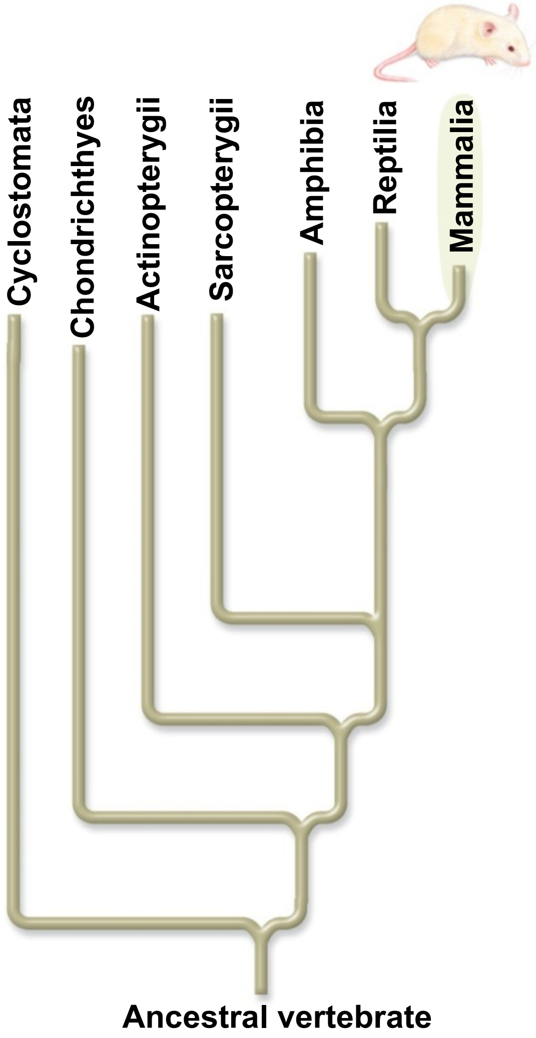
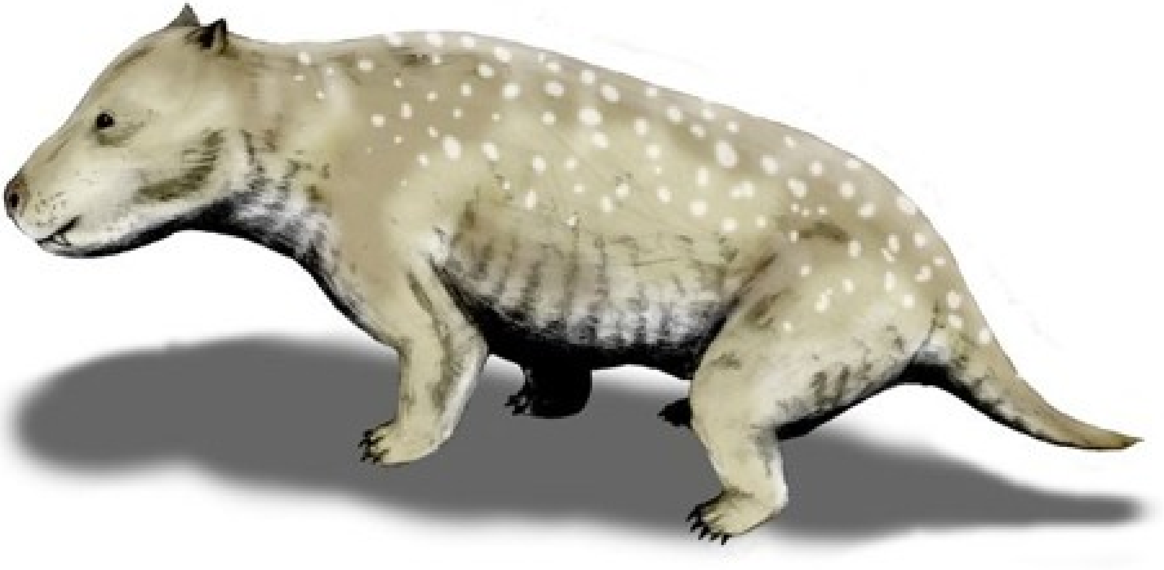


FIGURE 29.36



Cynodonts, which first appeared in the Late Permian period 260 million years ago, are thought to be the ancestors of modern mammals. (credit: Nobu Tamura)

Characteristics:

- **Mammary glands** secrete milk (evolutionary modification of apocrine (sweat) glands)
- Brain enlarged in large skull
- Single lower jaw bone (**dentary**)
- 3 **INNER EAR BONES** (malleus [hammer], incus [anvil] and stapes [stirrup])
- All mammals have **HAIR** (more or less)
- Skull with two **OCCIPITAL CONDYLES.**
- 7 **CERVICAL VERTEBRAE**
- **DIAPHRAGM**
- Non-nucleated Red Blood Cells
- Dioecious, internal fertilization,
- Endothermic and Homeothermic
- Only vertebrates with **SPECIALIZED TEETH**

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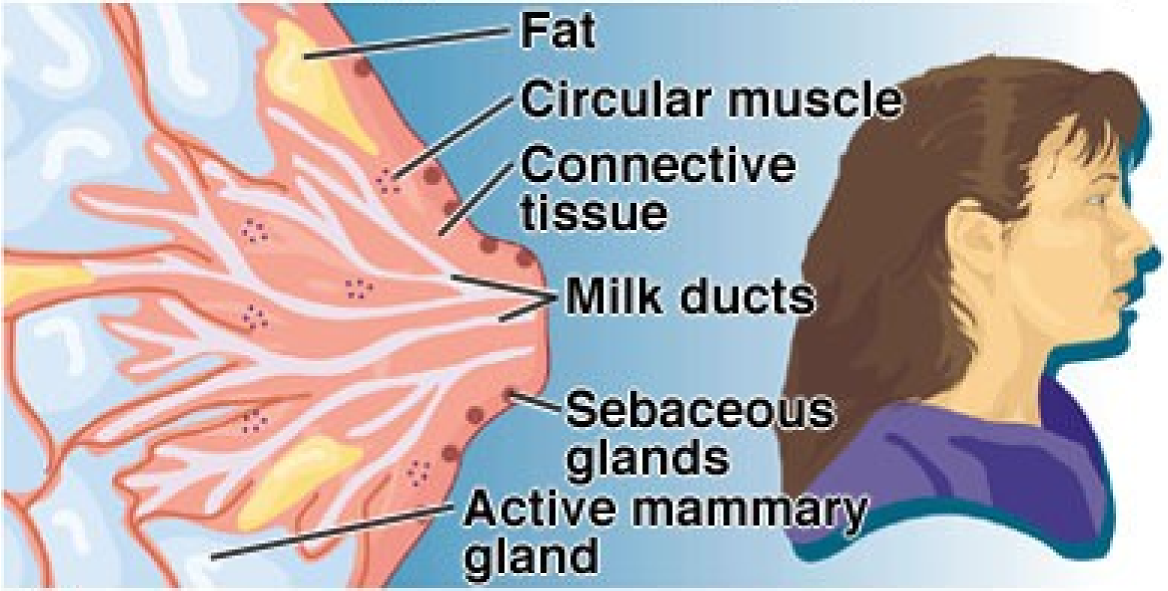
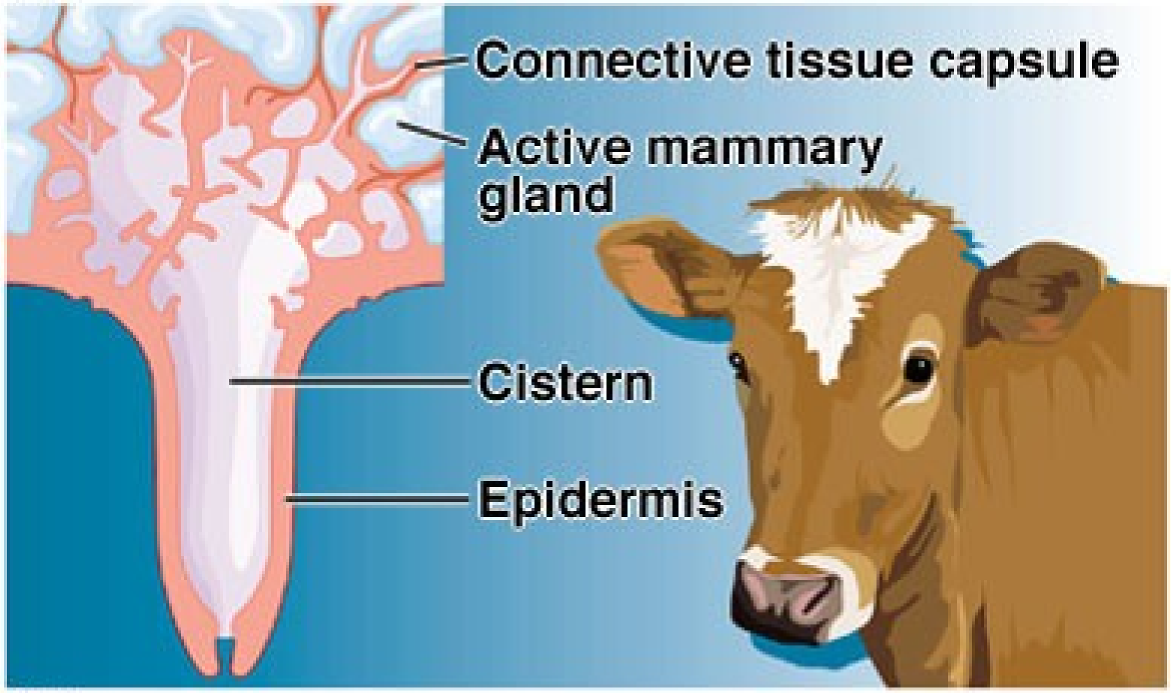
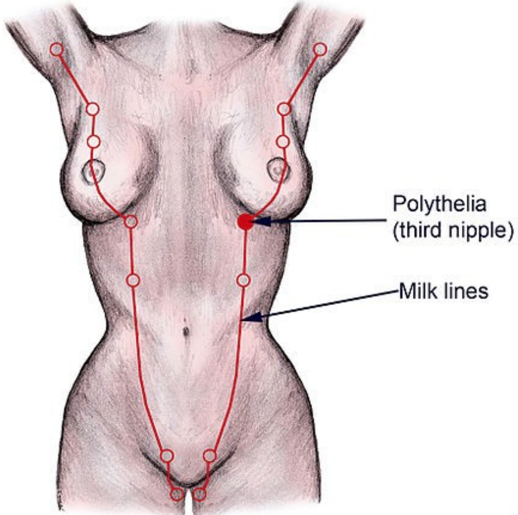
Mammary glands

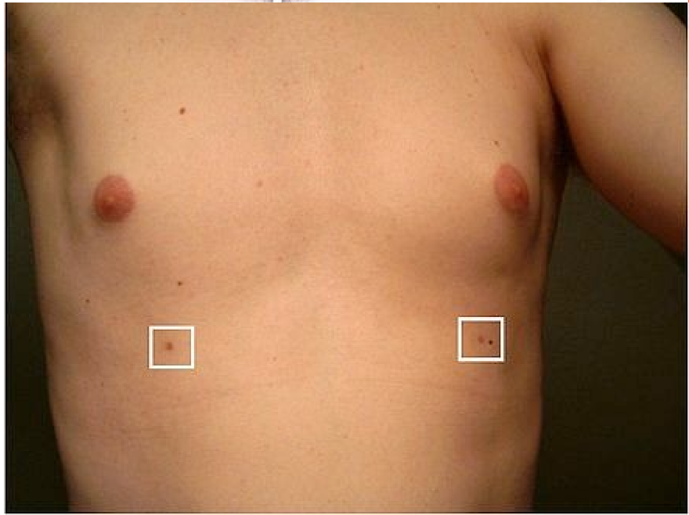


(a)



(b)





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(a) Sensory hairs

(b) Camouflaged coat

(c) Defensive quills

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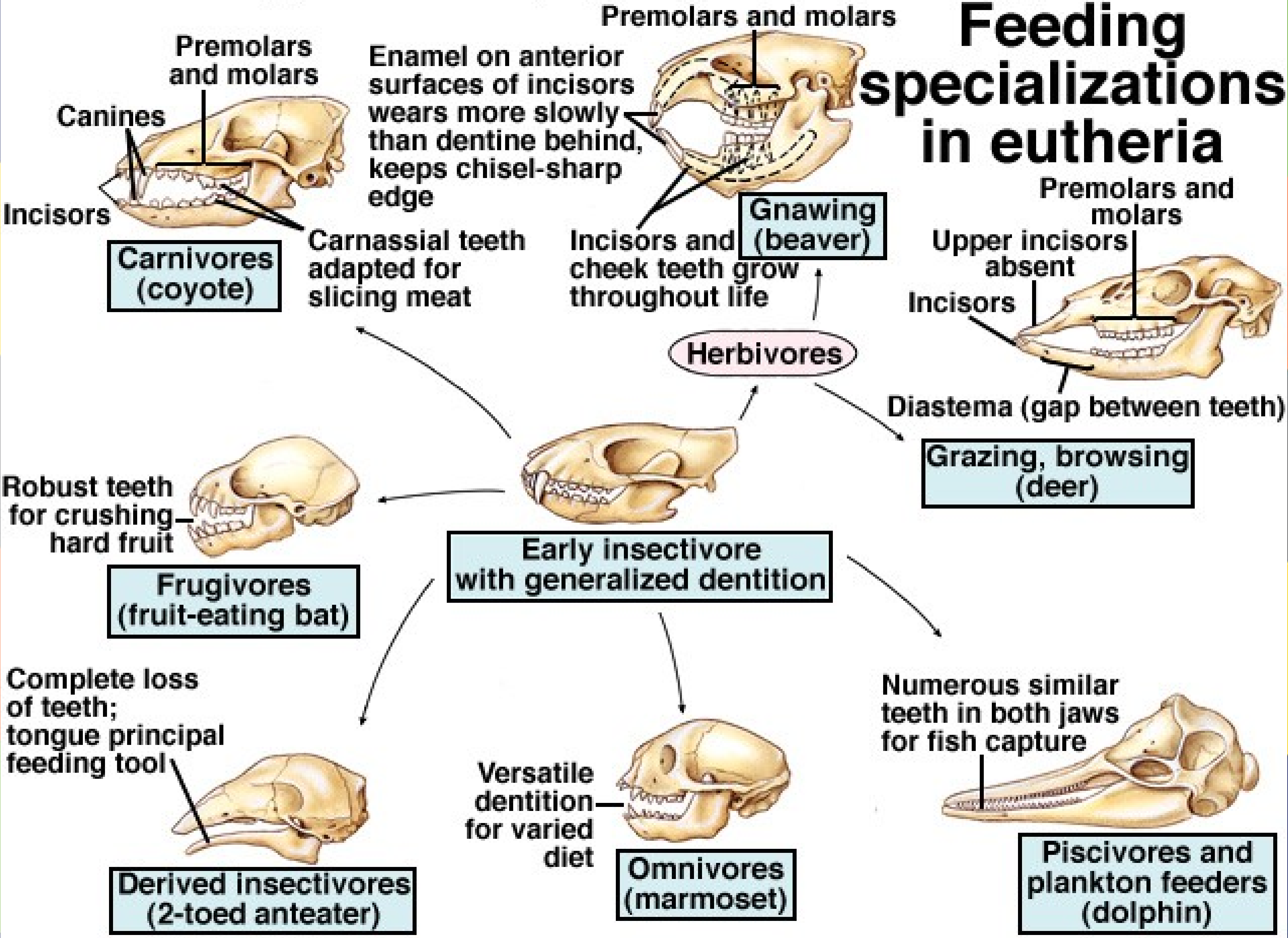
Feeding specializations in eutheria



Carnivores (coyote)

Carnassial teeth adapted for slicing meat

Enamel on anterior surfaces of incisors wears more slowly than dentine behind, keeps chisel-sharp edge

Incisors and cheek teeth grow throughout life

Gnawing (beaver)

Herbivores

Upper incisors absent

Diastema (gap between teeth)

Grazing, browsing (deer)

Robust teeth for crushing hard fruit

Frugivores (fruit-eating bat)

Early insectivore with generalized dentition

Complete loss of teeth; tongue principal feeding tool

Derived insectivores (2-toed anteater)

Versatile dentition for varied diet

Omnivores (marmoset)

Numerous similar teeth in both jaws for fish capture

Piscivores and plankton feeders (dolphin)

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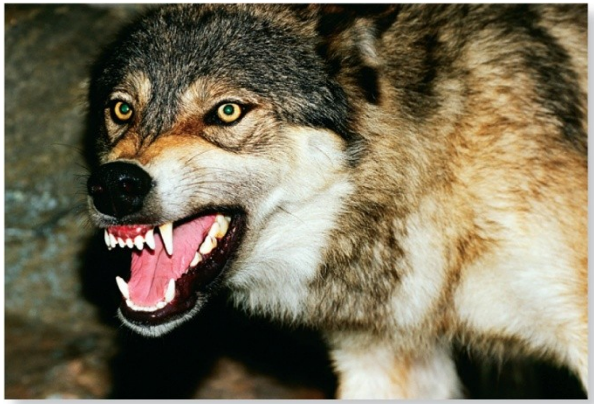
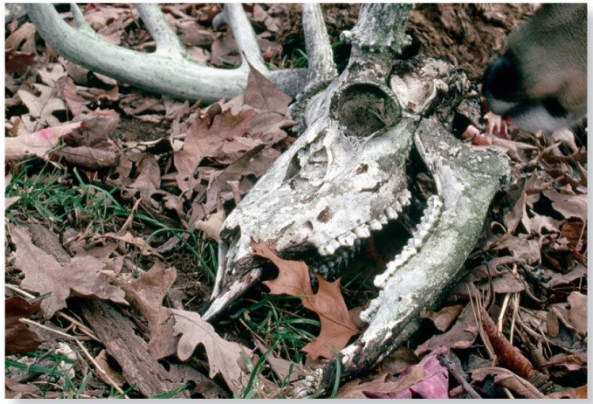
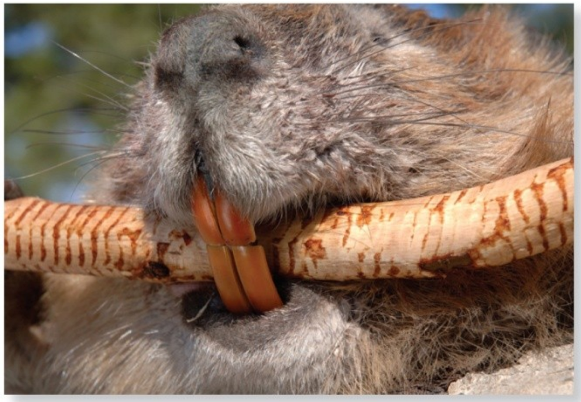


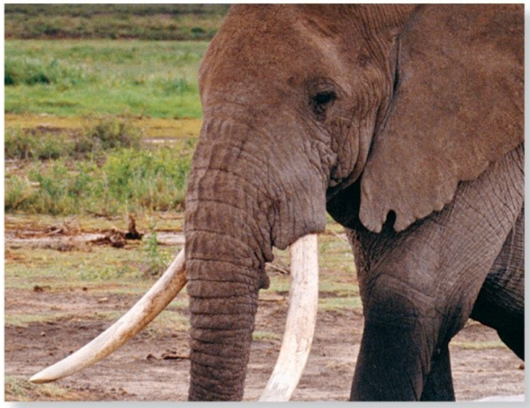
(a) Biting teeth



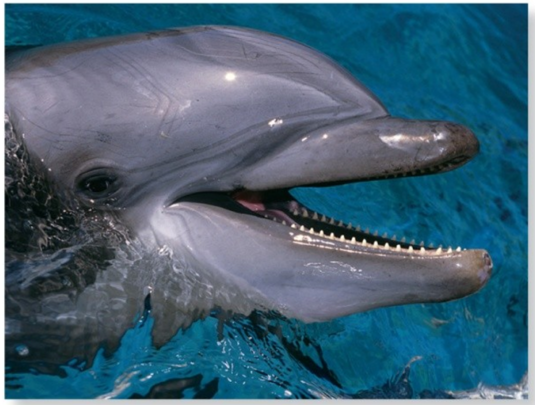
(b) Grinding teeth



(c) Gnawing teeth



(d) Tusks



(e) Grasping teeth

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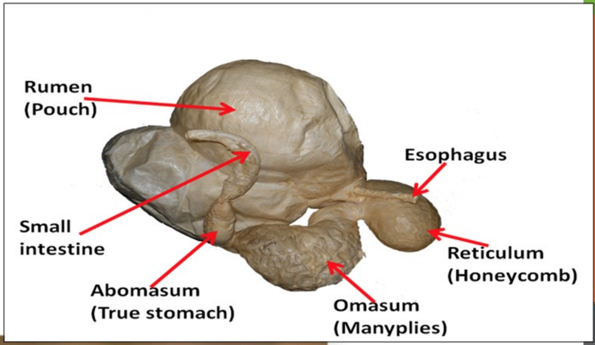
e: © Ken Lucas/Visuals Unlimited

Some but not all mammals

- ☐ Digest plants using **symbiotic bacteria**
- ☐ Have **horns and antlers**
  - Horns – bony outgrowth of skull
  - Antlers – entirely of bone



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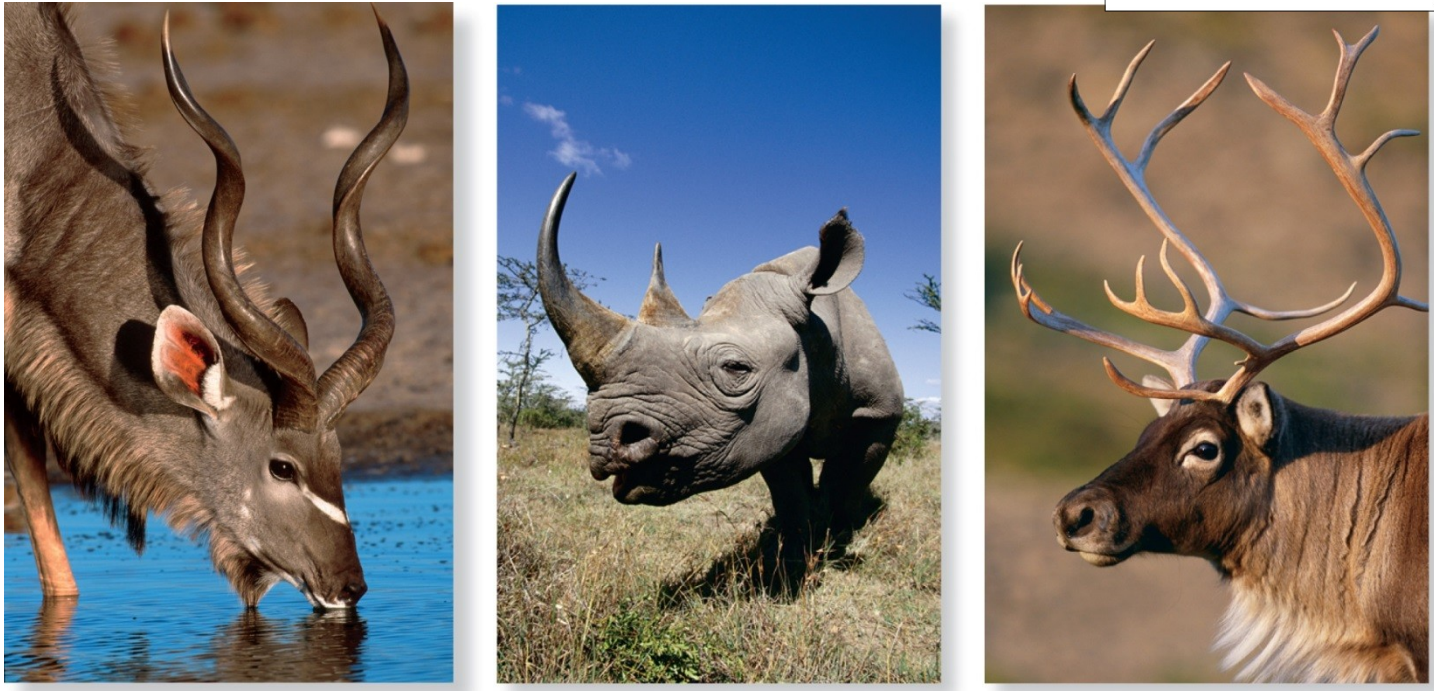

(a) Skull outgrowths **(b) Epidermal outgrowths** **(c) Bony antlers**

a: © MartinHarvey/Getty Images; b: © John Shaw/PhotoResearchers, Inc.; c: © Paul A. Souders/Corbis

Subclass **Prototheria** – Order **Monotremata**

- **Platypus** and **echidna** lay eggs, lack placenta, have poorly developed nipples

Subclass **Theria “Wild beast”**

- Clade Metatheria - **marsupials**
  - 7 orders
  - Once widespread, now confined mostly to Australia
  - Virginia Opossum found in North America
  - Very undeveloped young must make it to **marsupium** (pouch) to finish development

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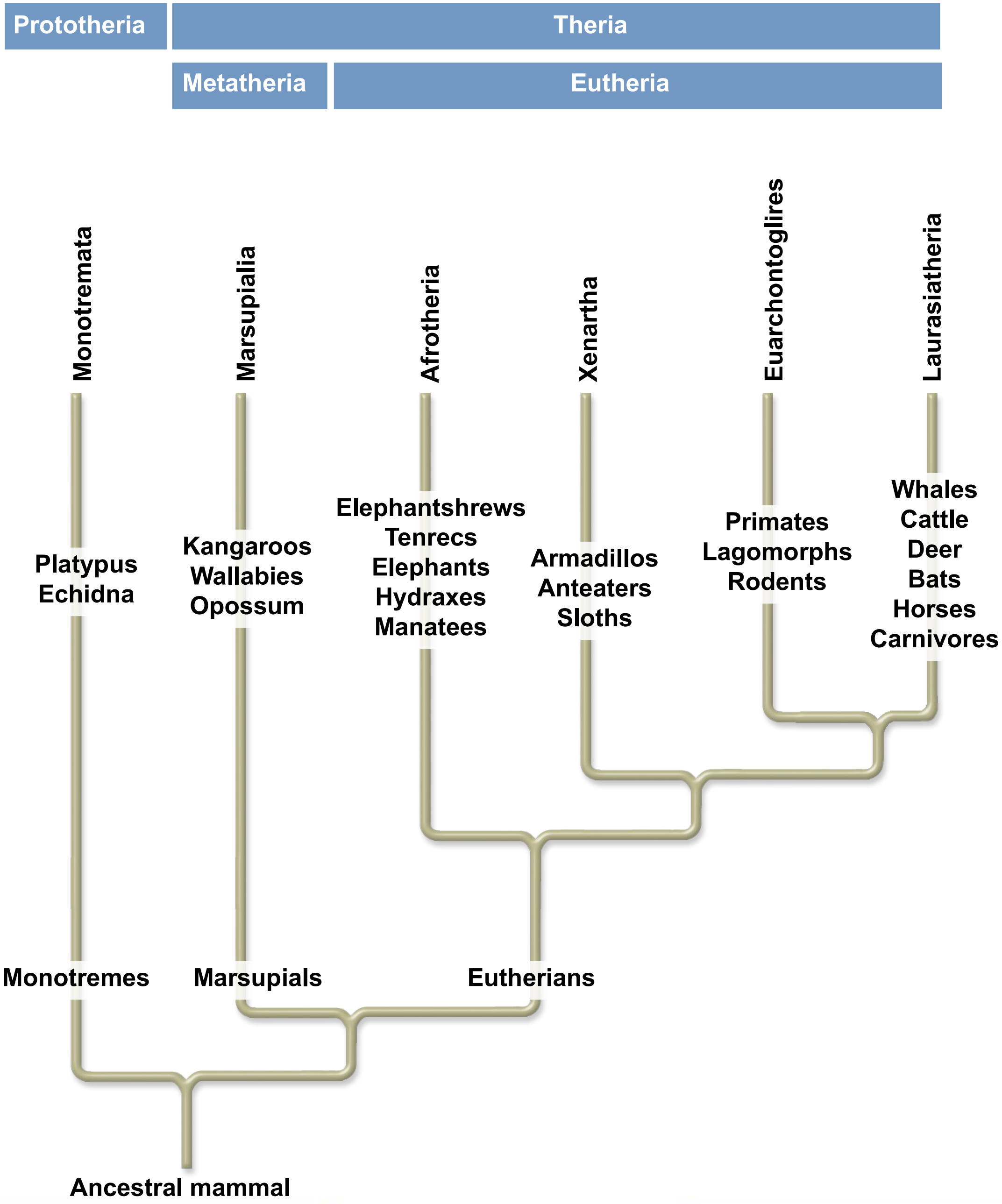

MONOTREMES

Oviparous - egg laying mammals

Gut, ureters, and reproductive tract all empty into a CLOACA (similar to reptiles and birds). Mammal embryos, including humans, also have cloaca.

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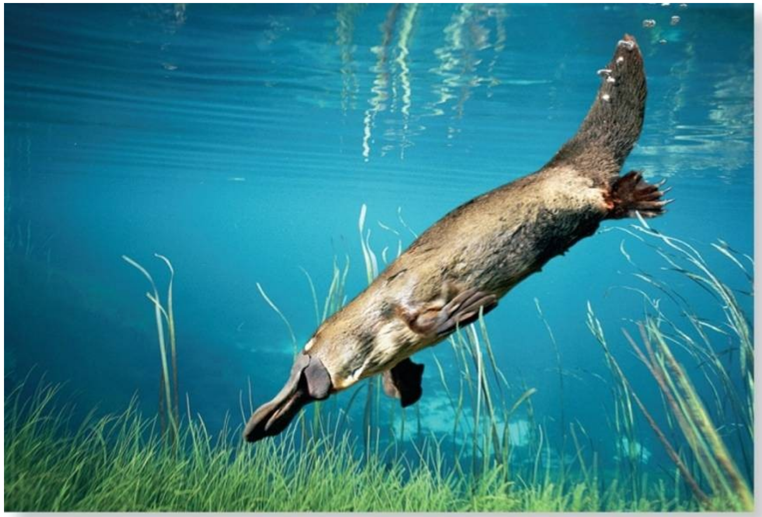
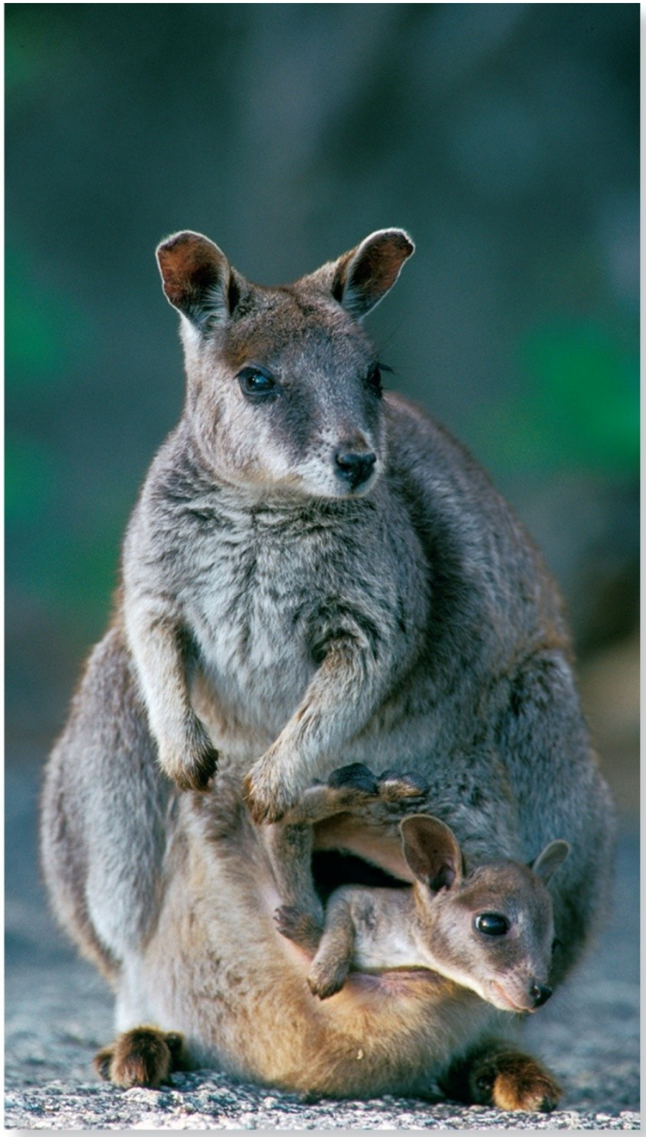


(a) Prototherian (duck-billed platypus)



(b) Metatherian (rock wallaby)

a: © Dave Watts/naturepl.com; b: © Theo Allofs/Visuals Unlimited

MARSUPIALS

Pouched mammals

Most found in Australia

Young born at early stage of development and develop in mother’s pouch

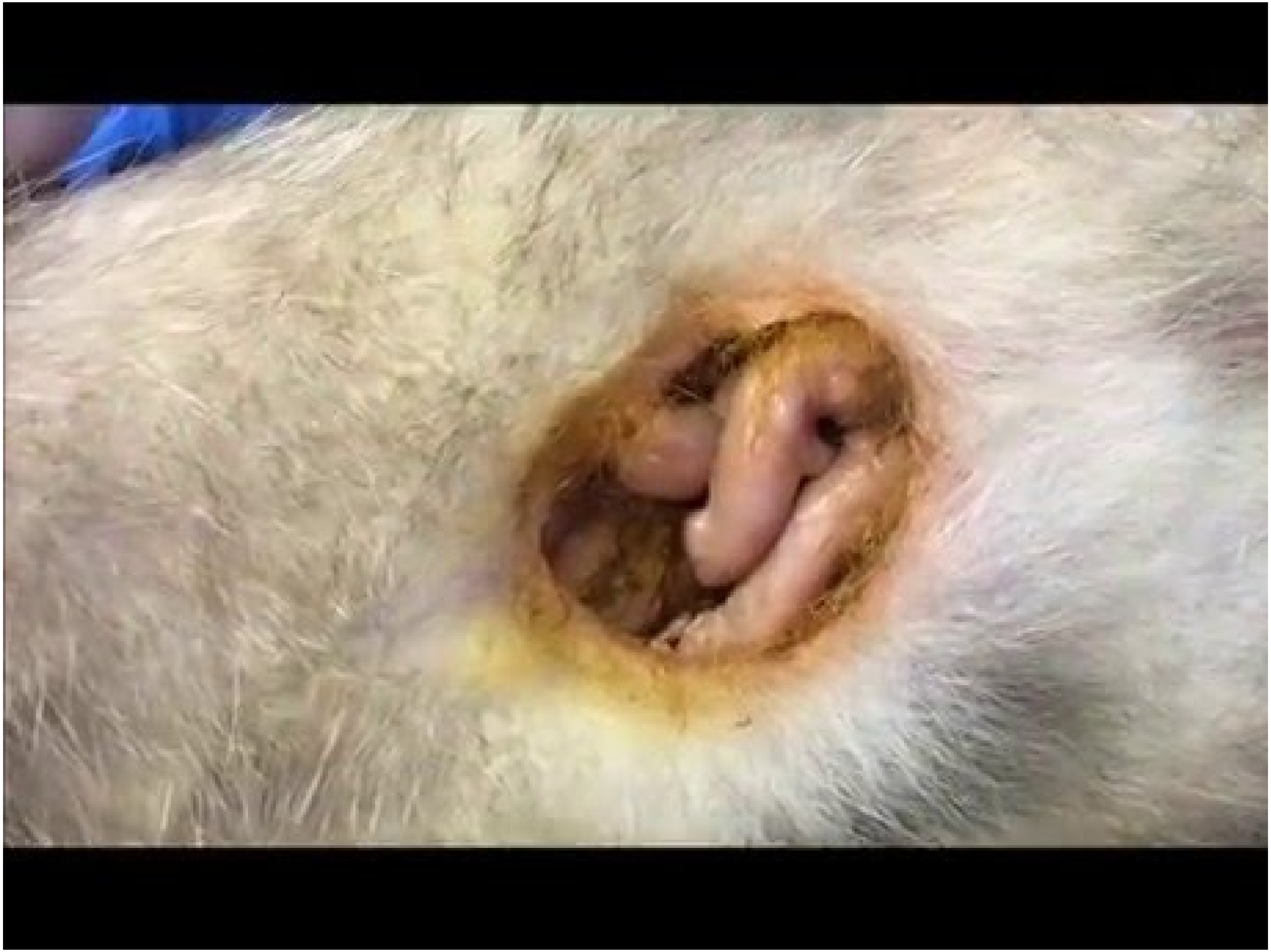
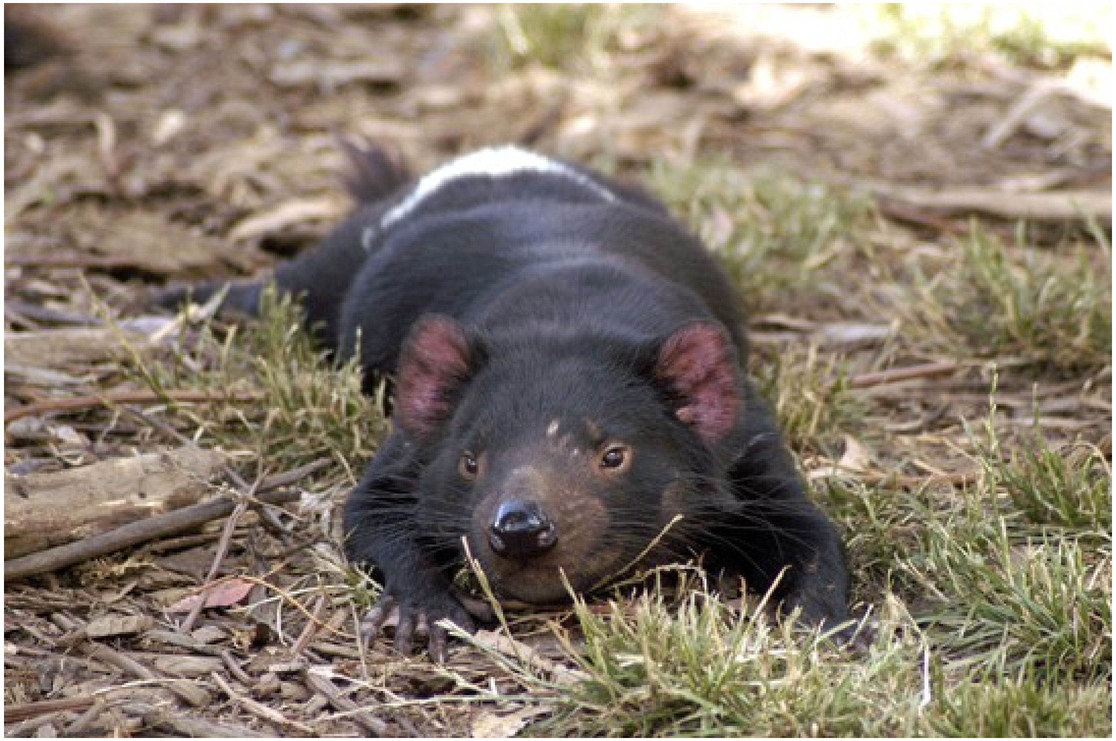


FIGURE 29.38



The Tasmanian devil is one of several marsupials native to Australia. (credit: Wayne McLean)

Subclass **Theria** – Clade **Eutheria**

- Placental mammals
- Long-lived complex placenta
- Prolonged gestation

EUTHERIANS

Viviparous – young develop within female’s body, and are born as juveniles

Egg develops in a uterus (womb) with placental attachment

E.g. Humans, Bats, Horses, Rabbits, etc.

ORDER EULIPOTYPHLA

Insect-eating mammals

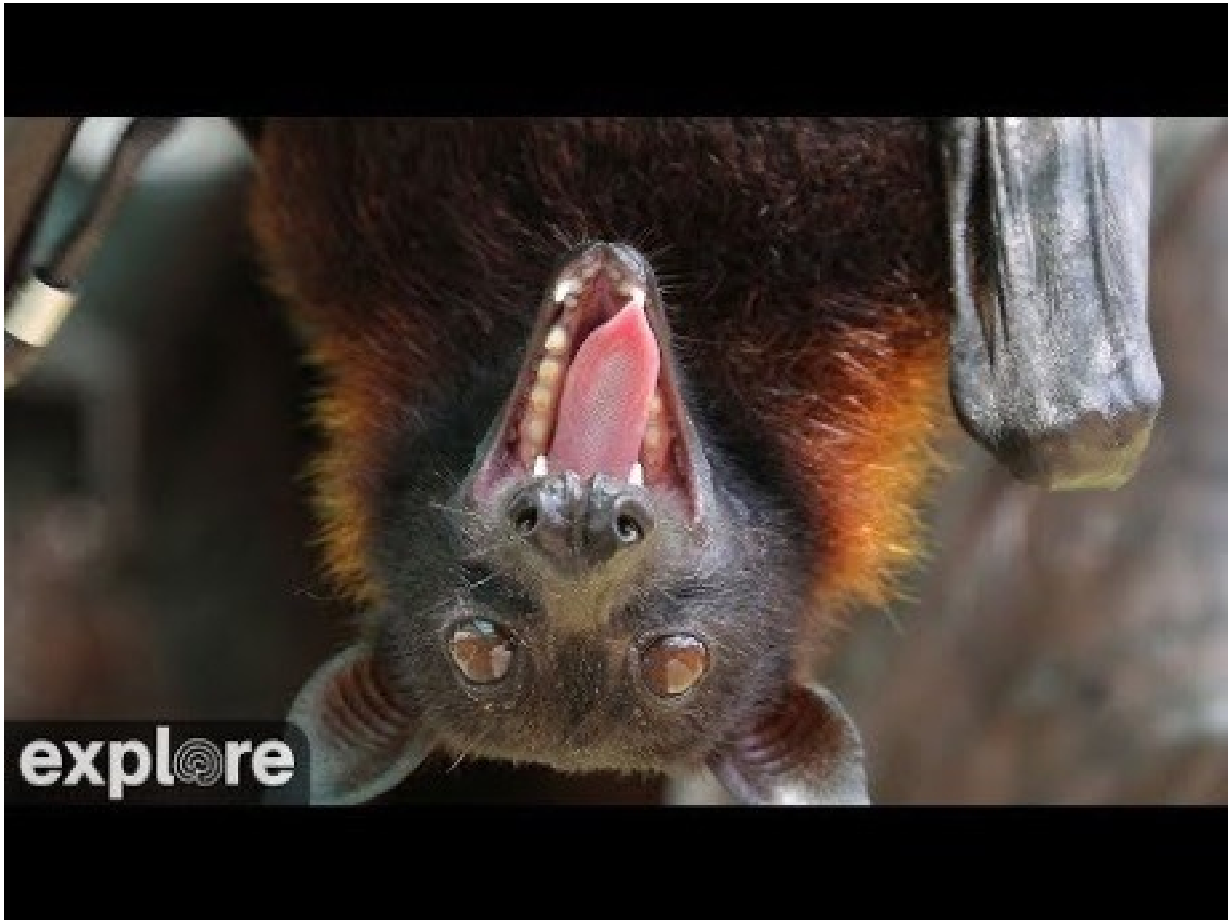
Shrew, hedgehogs, moles

Solenodons and shrews have venomous saliva.

ORDER CHIROPTERA

- Flying mammals
- Echolocation used for flying and locating food
- Mostly nocturnal

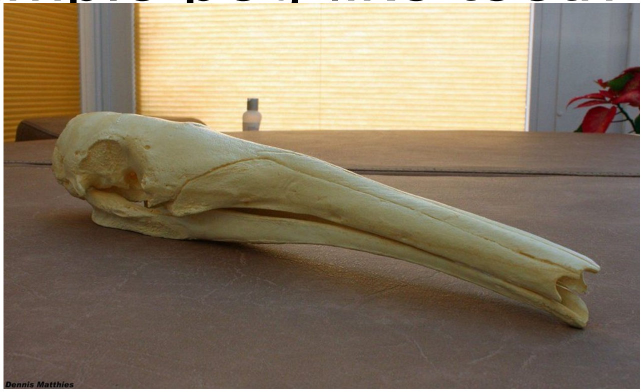
BATS FLYING FOXES



ORDER XENARTHRA

Anteaters – Toothless

Armadillos and Sloths - Simple peg-like teeth



Armadillo - usually a bump on the highway

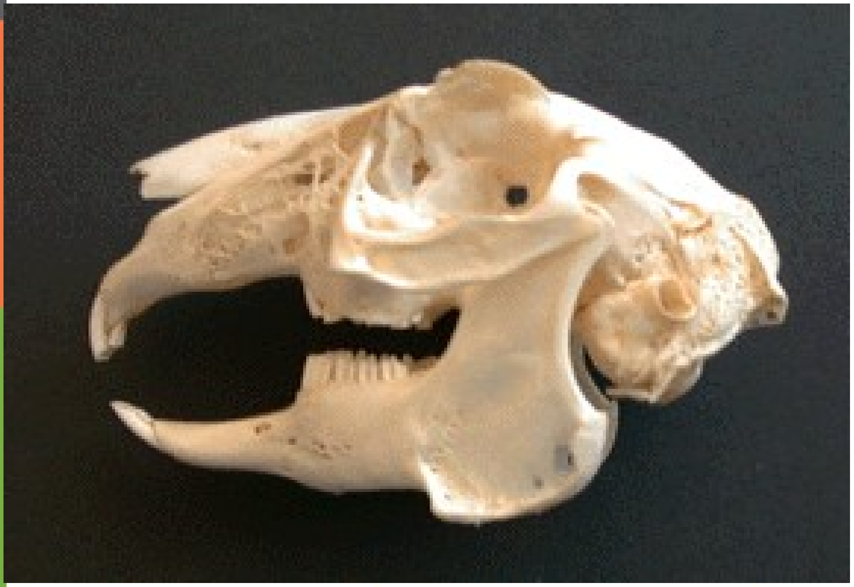
ORDER RODENTIA

- Gnawing Mammals
- Largest group of mammals (40%)
- Dentition – two upper and two lower chisel-like incisors that grow continuously
- Squirrels, rats, beavers

ORDER LAGOMORPHA

Dentition similar to rodents but with four upper incisors rather than two

Rabbits, hares, pikas



ORDER CARNIVORA

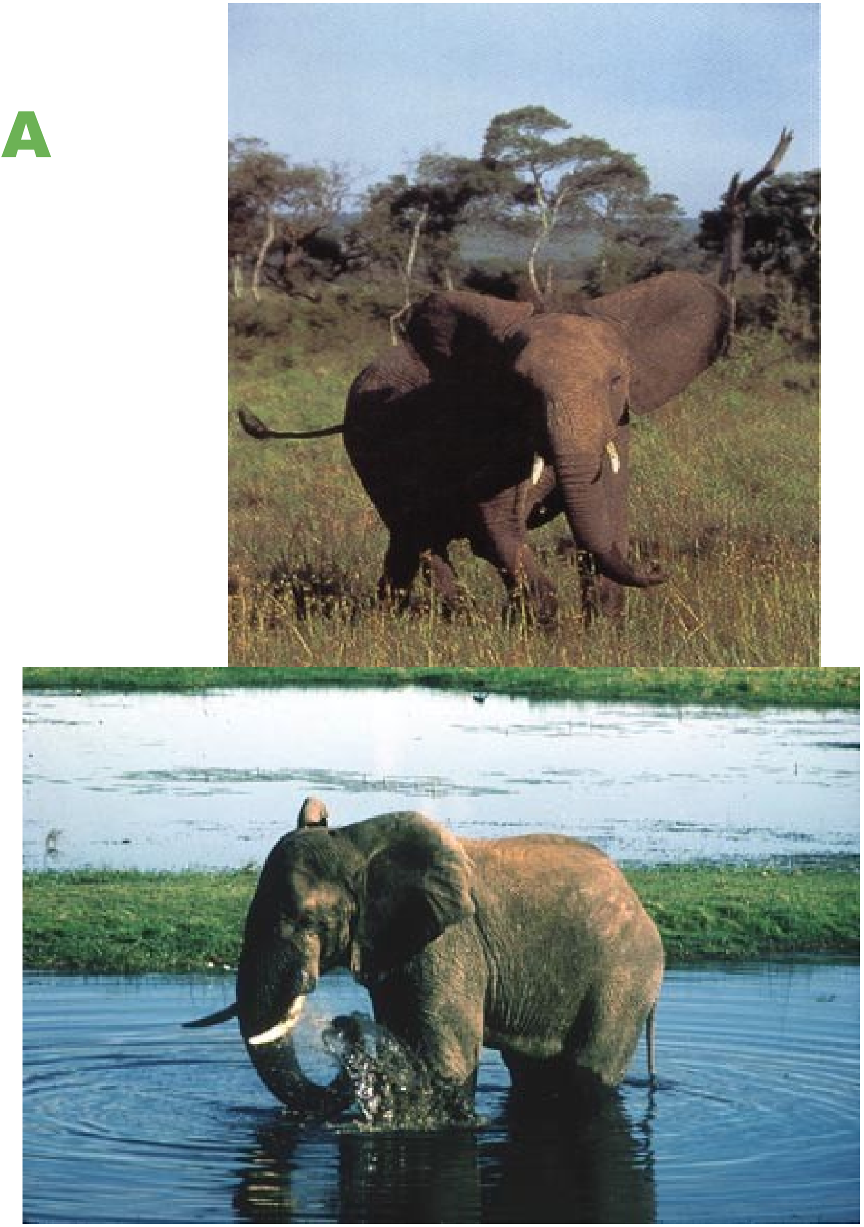
Flesh eating mammals

Teeth adapted for tearing flesh

Dogs, cats, bears, (sea lions, walruses)

ORDER PROBOSCIDEA

- Proboscis mammals – mammals with an elongated snout or trunk
- Two upper incisors elongated as tusks
- Molars well developed for chewing
- Elephants



ORDER PERISSODACTYLA

Odd-toed hoofed mammals (1 or 3)

Herbivorous

Teeth adapted for chewing

Horses, zebras, asses, rhinoceroses, tapirs

CETARTIODACTYLA

The next two orders have recently been combined into a single taxon – the Cetartiodactyla

ARTIODACTYLA

- Even-toed hoofed mammals (2 or 4)
- Many possess horns or antlers
- Many are ruminants
  - Four part stomachs
- Deer, cattle, sheep, swine, camels

CETACEA

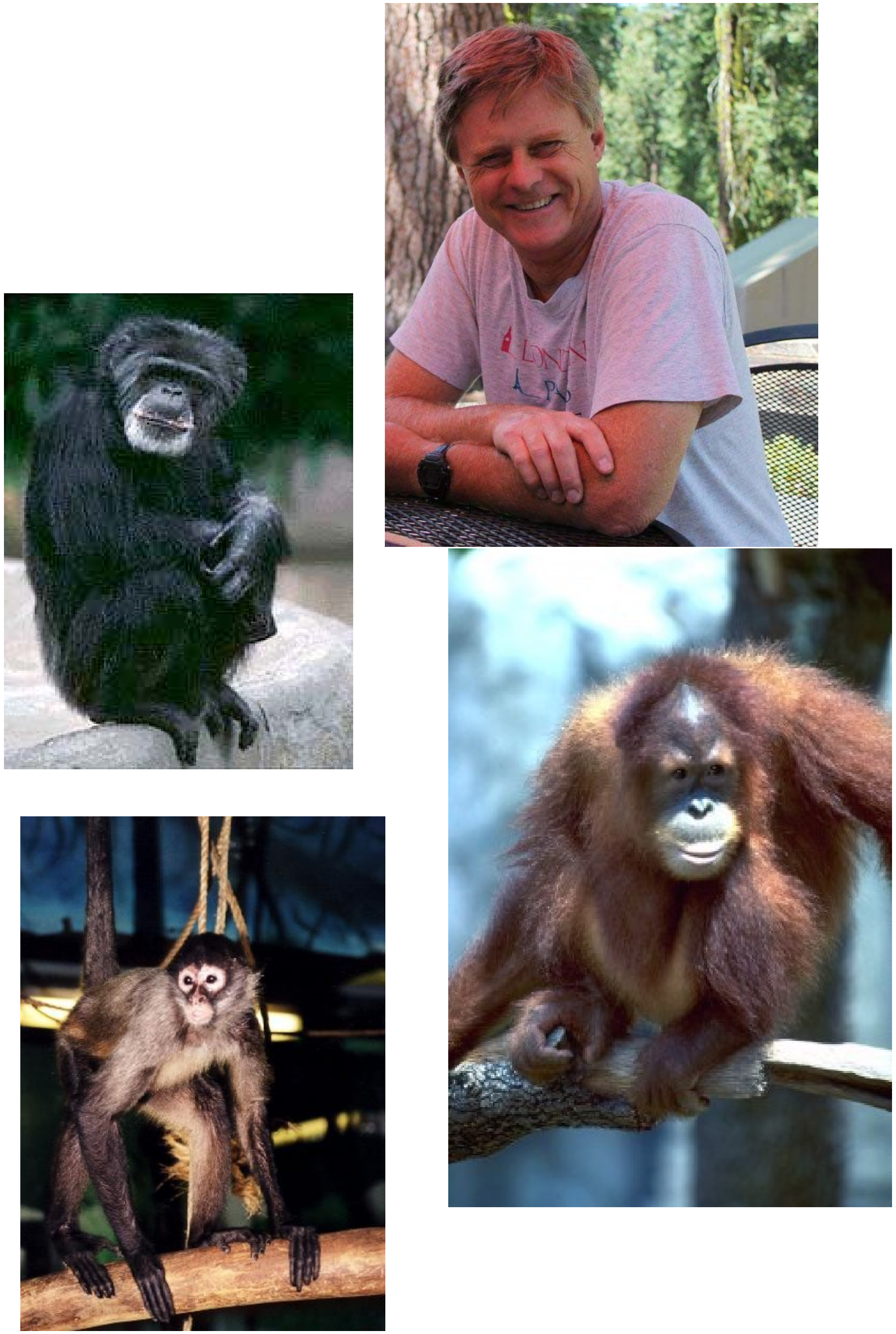
Anterior limbs modified into flippers

Nostrils represented by blowhole on top of head

Hair limited to a few hairs on muzzle

ORDER PRIMATES

- Five digits on both forelimbs and hindlimbs
- Opposable thumbs
- E.g. Humans, monkeys, apes



PRIMATES

Primarily tree-dwelling species

Evolved about 85 mya

Defining characteristics

- Grasping hands with opposable thumbs and big toe
- Large brain
- Some digits have flat nails (not claws)
- Binocular vision (stereoscopic vision)
- Complex social behavior and well-developed parental care

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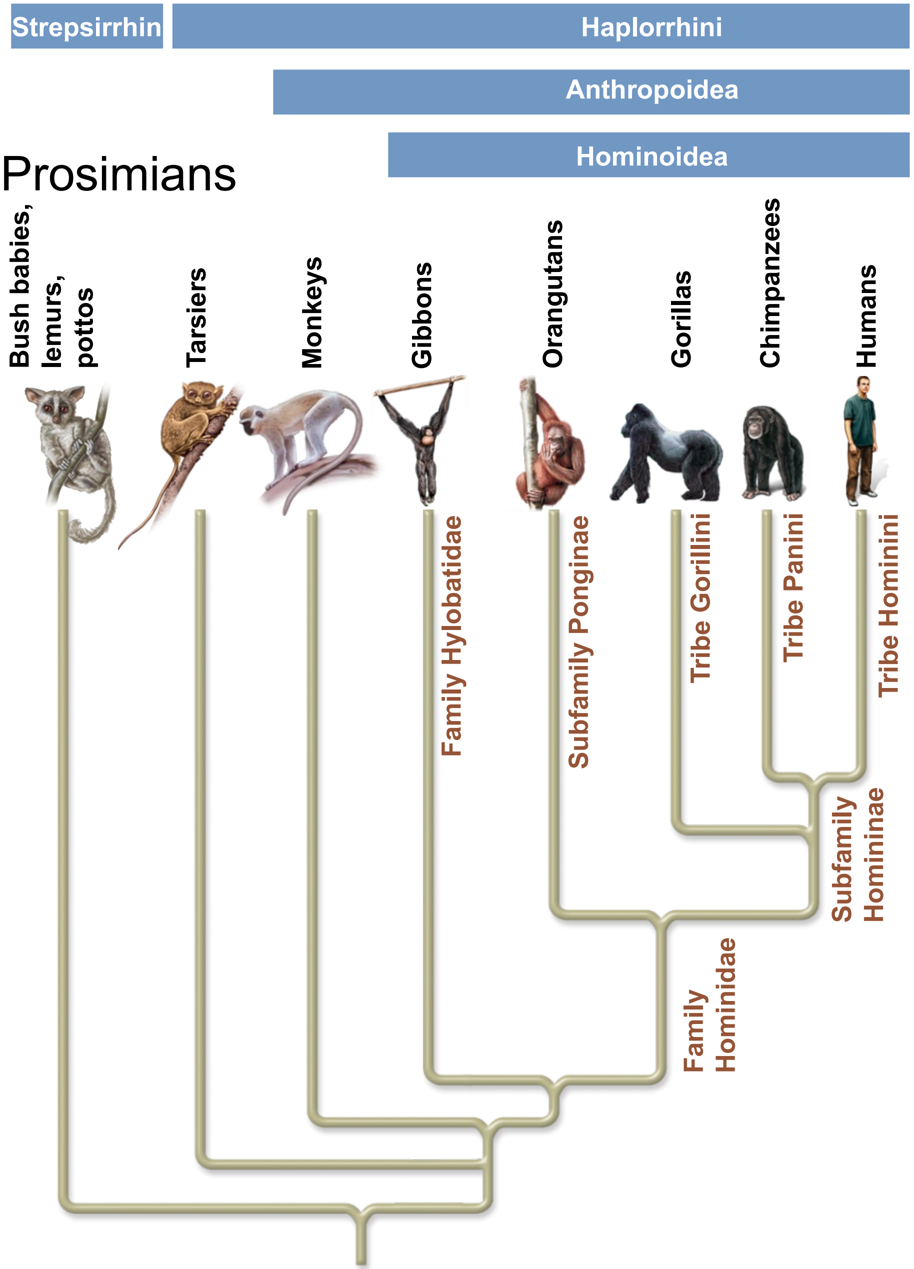


Strepsirrhin

Haplorrhini

Anthropoidea

Hominoidea

Prosimians

Bush babies, lemurs, pottos

Tarsiers

Monkeys

Gibbons

Orangutans

Gorillas

Chimpanzees

Humans

Family Hylobatidae

Subfamily Ponginae

Tribe Gorillini

Tribe Panini

Tribe Hominini

Subfamily Homininae

Family Hominidae

STREPSIRRHINES

"Wet" nose

Small brain

Good sense of smell

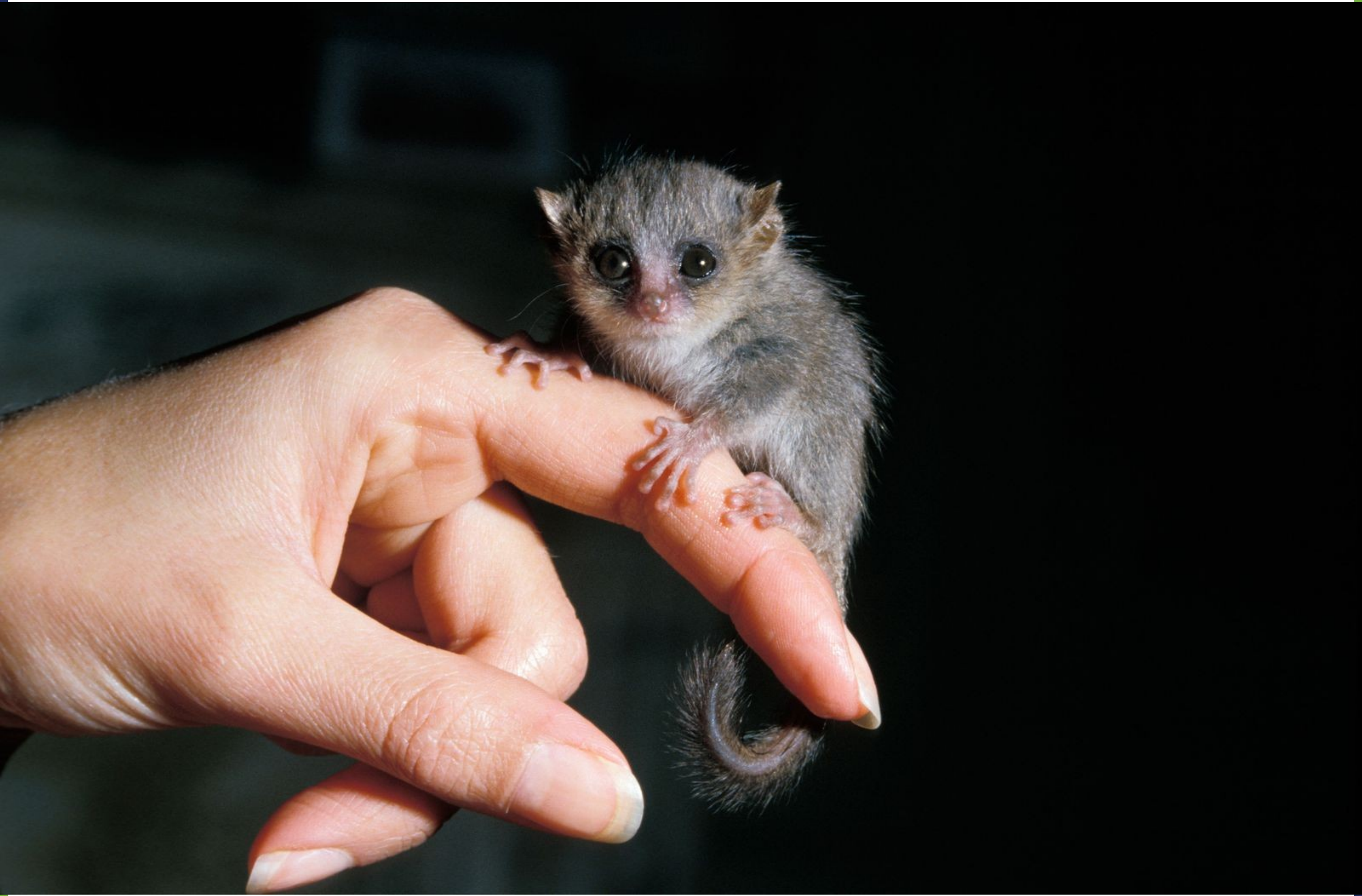
Organ to detect pheromones

Split uterus (bicornuate)

Make their own vitamin C

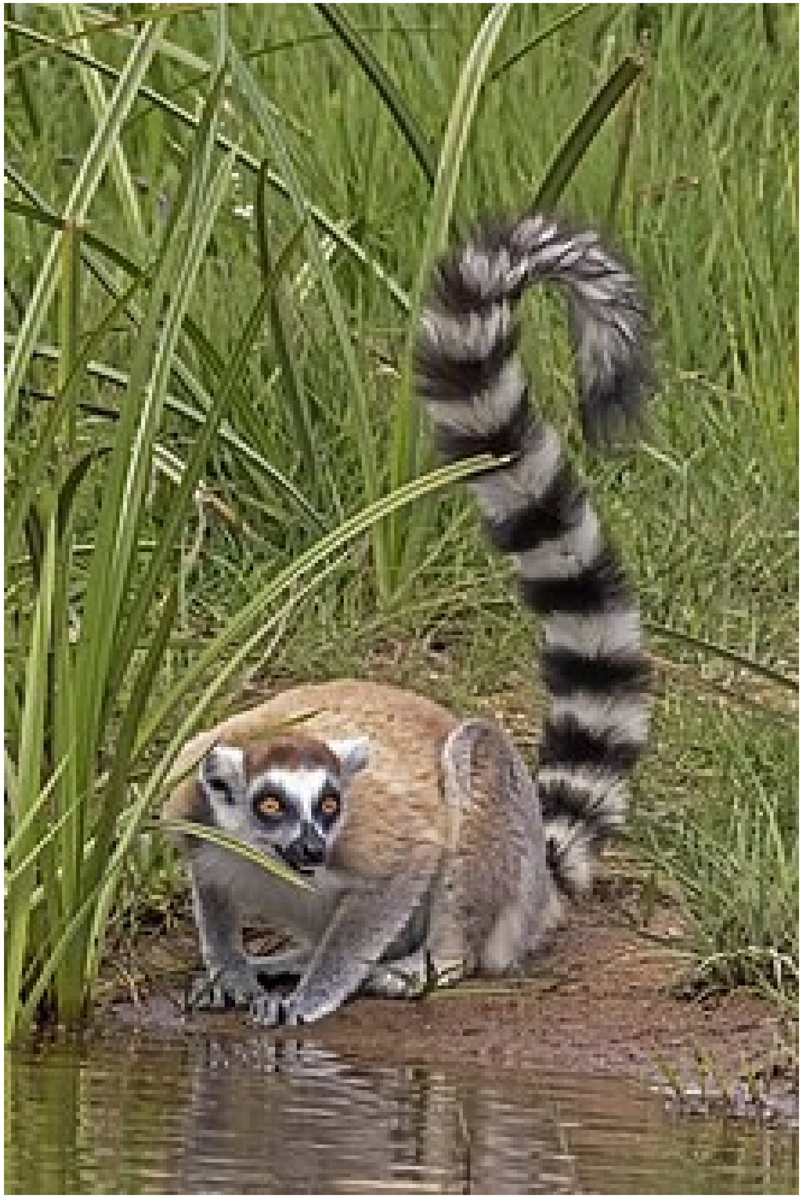
Lemurs, Aye-ayes, lorises, galagos

Mouse lemur

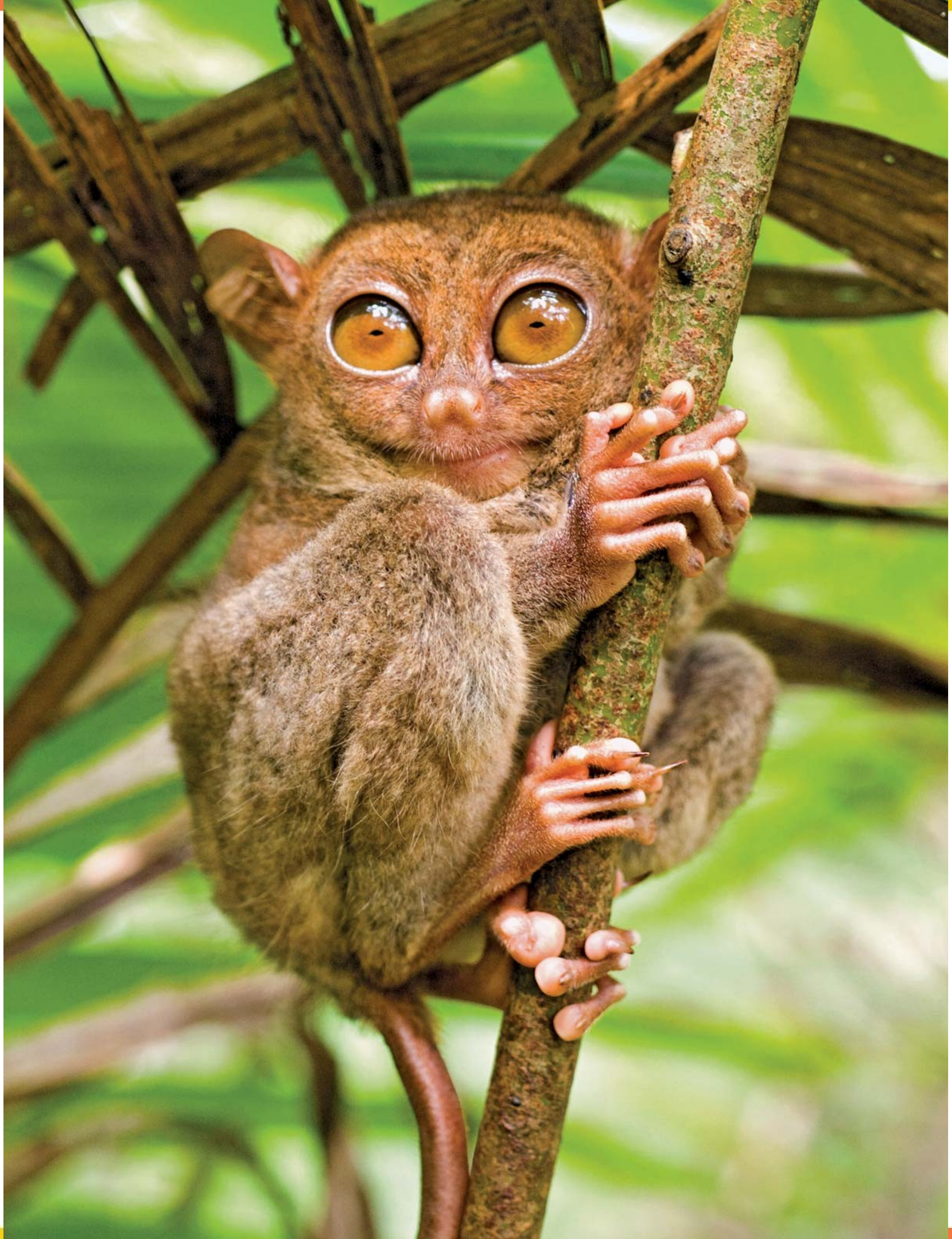


Aye-aye

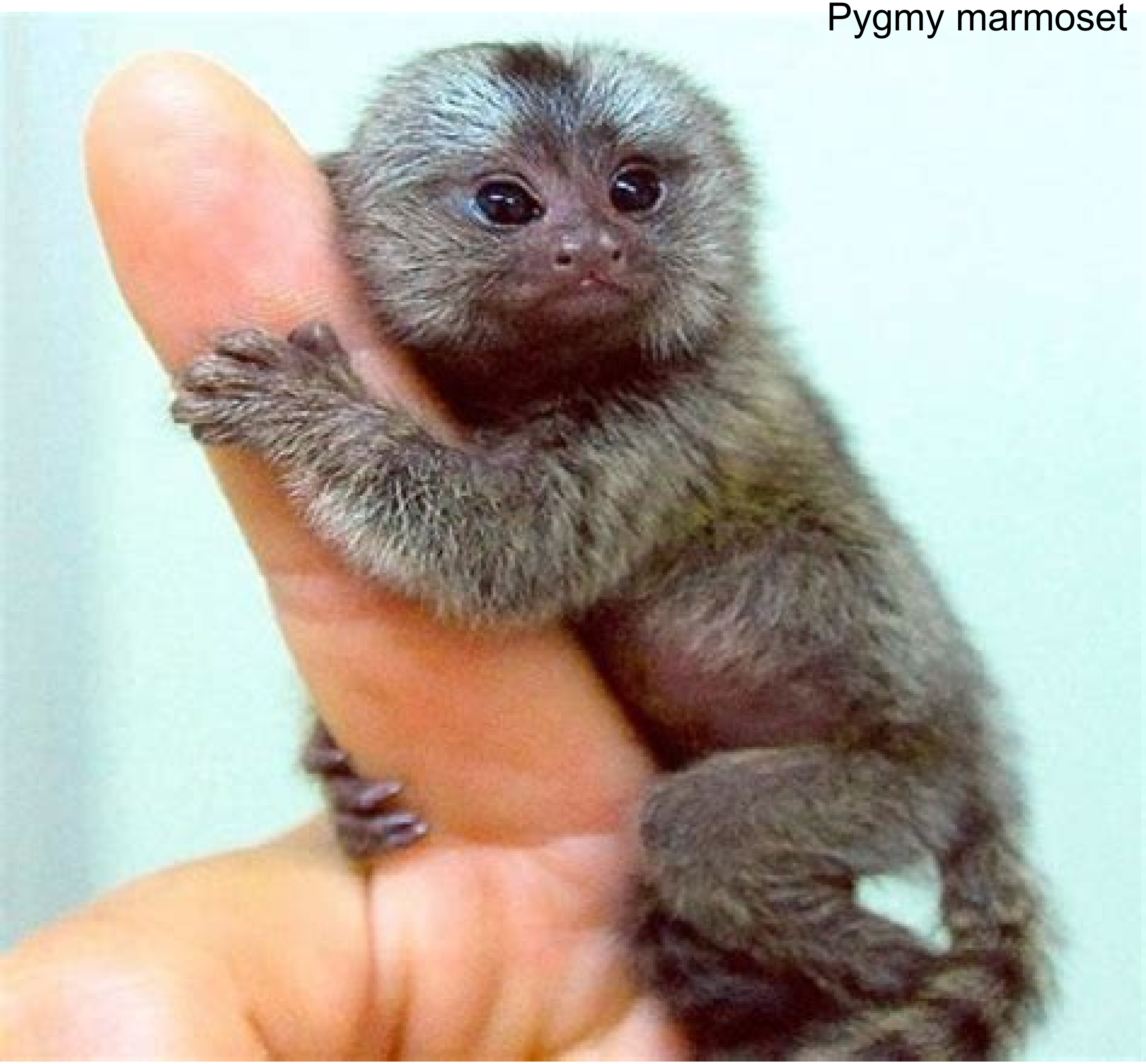
Ring-tailed lemur



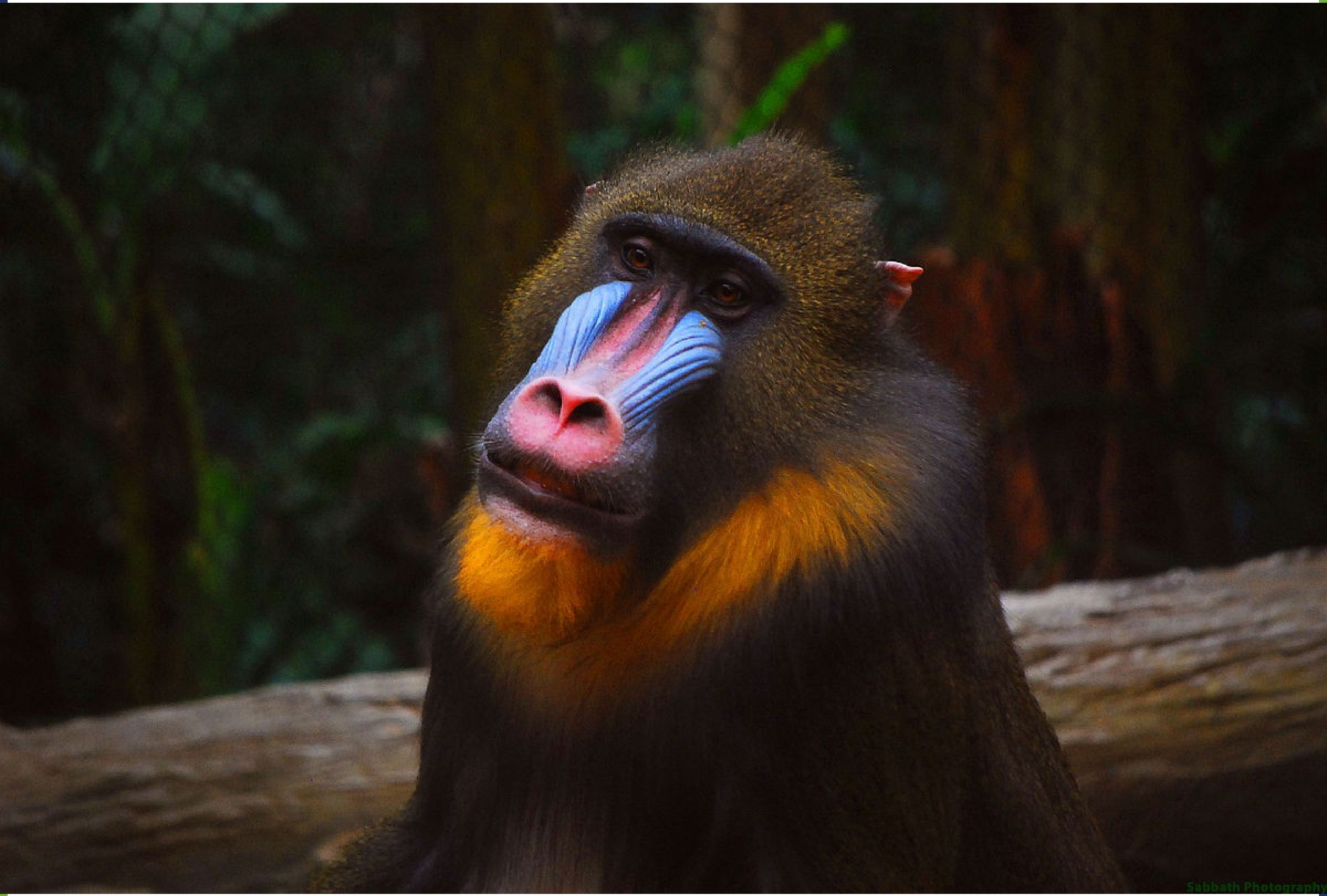
Tarsier



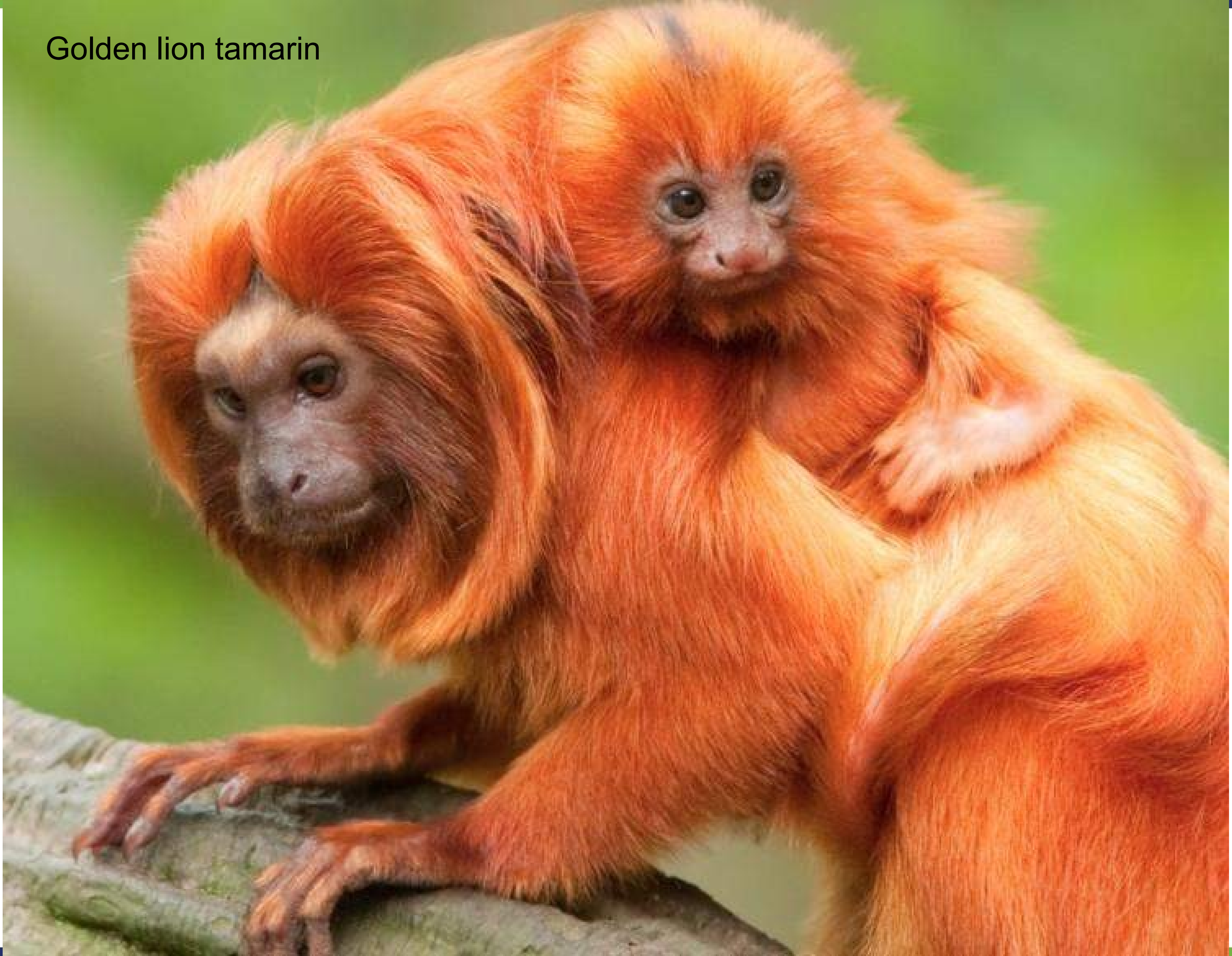
Pygmy marmoset



Mandrill



Golden lion tamarin



- **Monkeys**
  - Tails, no **brachiation**, usually smaller
- **Hominoids** – gibbons, gorillas, orangutans, chimpanzees and humans
  - No tails, **brachiation**, usually larger
  - Family Hylobatidae – lesser apes or gibbons and siamangs
  - Family Hominidae – greater apes
- Adaptations for swinging in trees:
  - Rotating shoulder joint
  - Big toe separated from other toes
  - Thumb separated from other fingers (for gripping branches)
  - **Stereoscopic vision**

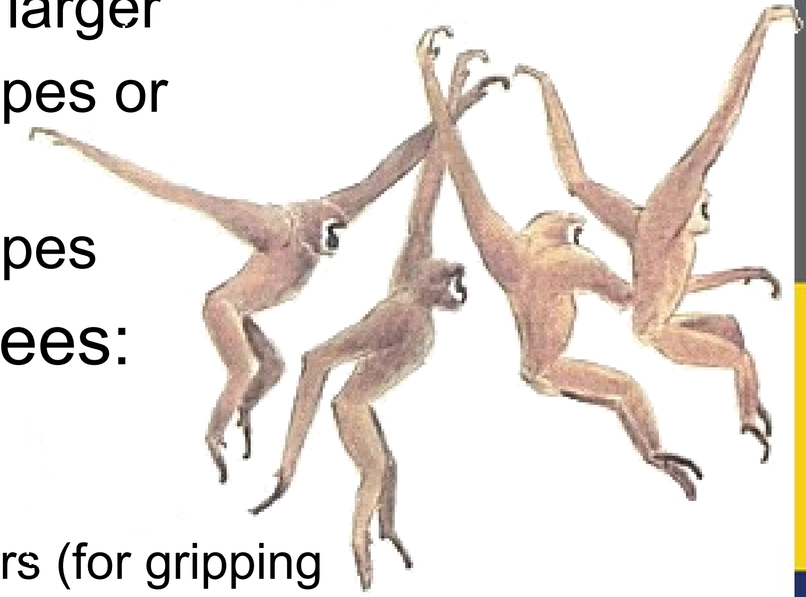
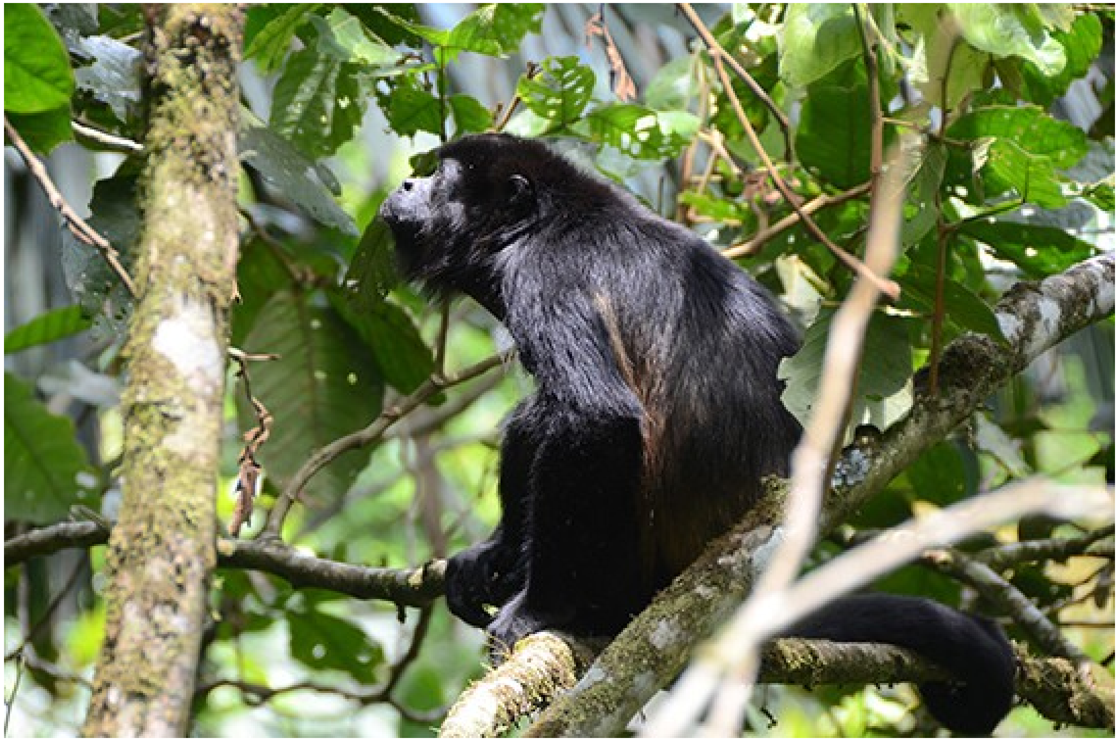


FIGURE 29.39



The howler monkey is native to Central and South America. It makes a call that sounds like a lion roaring. (credit: Xavi Talleda)

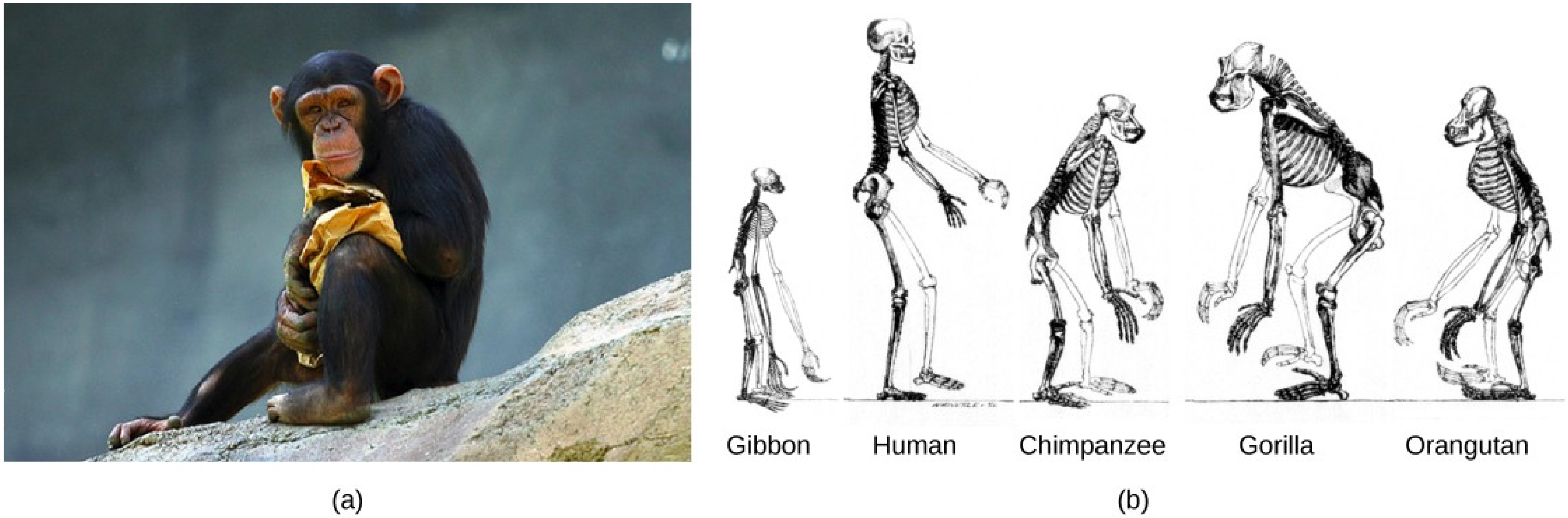
Humans very closely related to chimpanzees and apes but **did not evolve directly** from them

All **hominoids** (greater and lesser apes) shared a common ancestor

Family Hominidae

- ☐ Subfamily Ponginae – **orangutans**
- ☐ Subfamily Homininae
  - Tribe Gorillini – **gorillas**
  - Tribe Panini – **chimpanzees**
  - Tribe Hominini– **humans** and **their ancestors**

FIGURE 29.40



The (a) chimpanzee is one of the great apes. It possesses a relatively large brain and has no tail. (b) All great apes have a similar skeletal structure. (credit a: modification of work by Aaron Logan; credit b: modification of work by Tim Vickers)

HUMAN EVOLUTION

About 6 mya, lineage split off from other primates. New adaptation was bipedalism.

Evolution not a neat progression

1 or 2 (or more) **Hominin** species coexisted at the same time. Hominins are groups that gave rise to humans, such as *Australopithecus* and *Homo erectus*, as well as cousins like Neanderthals

Key characteristic was **bipedalism**

- ❑Resulted in many changes – spine sits underneath skull, broader pelvis, lower limbs larger

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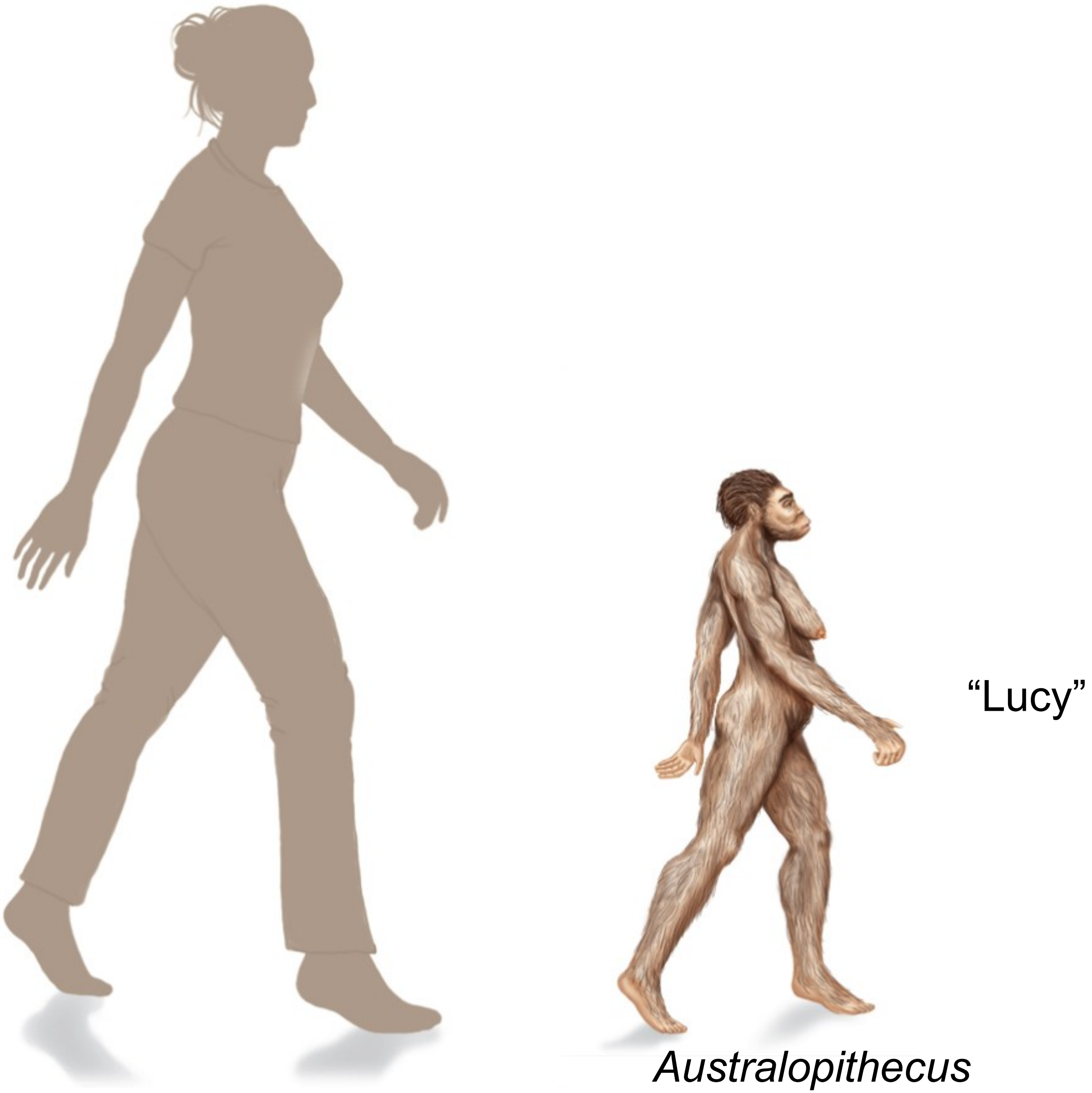
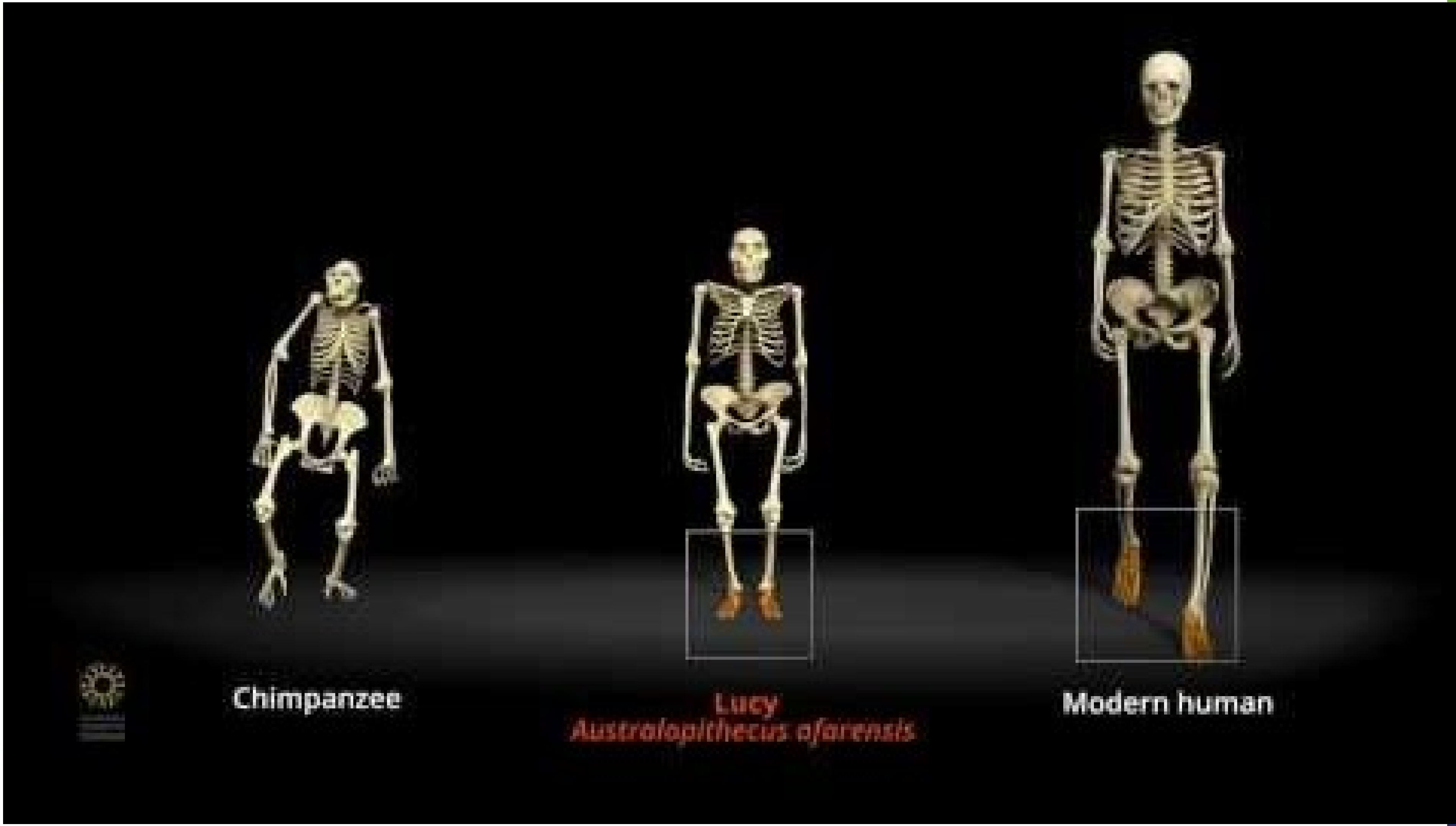
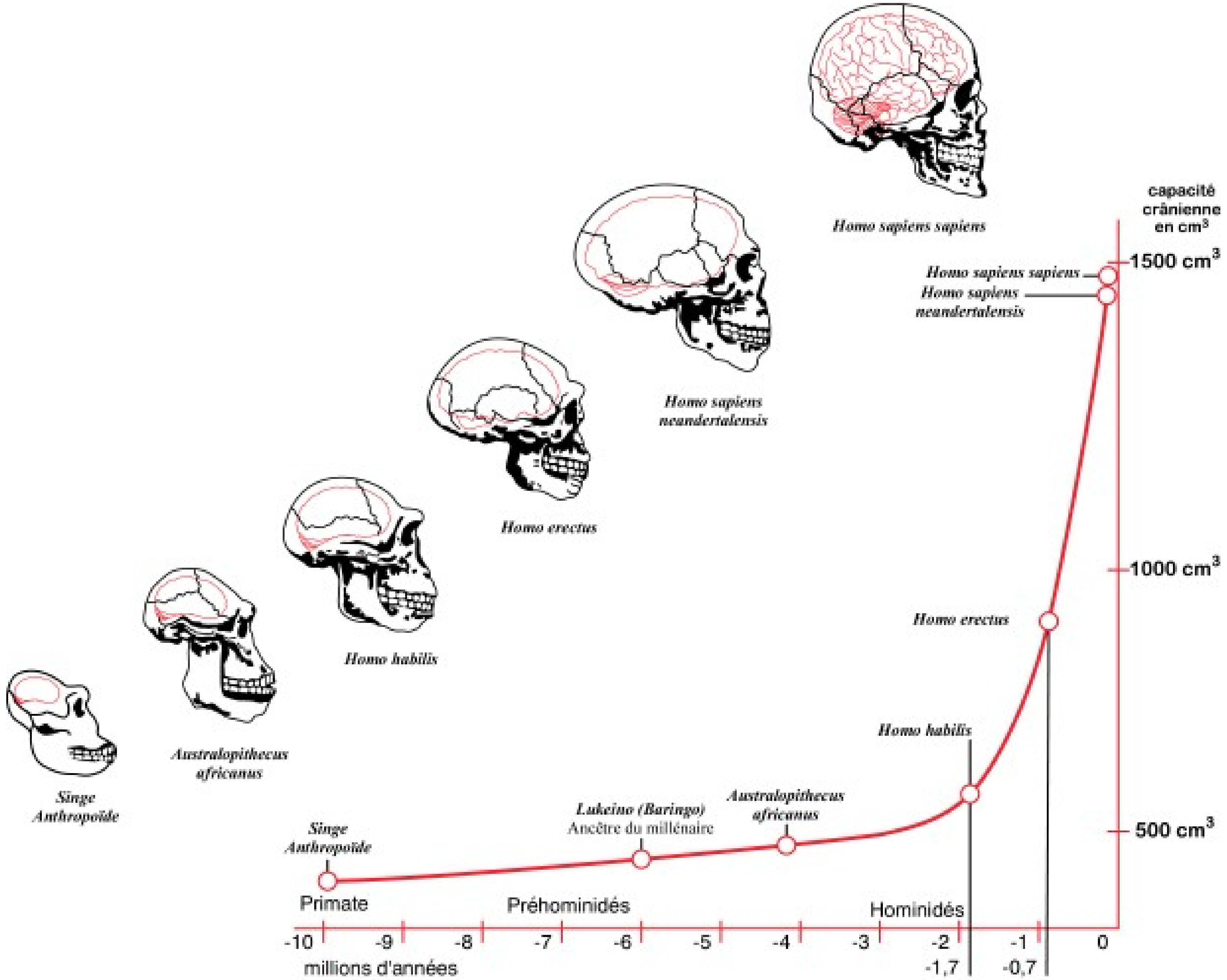


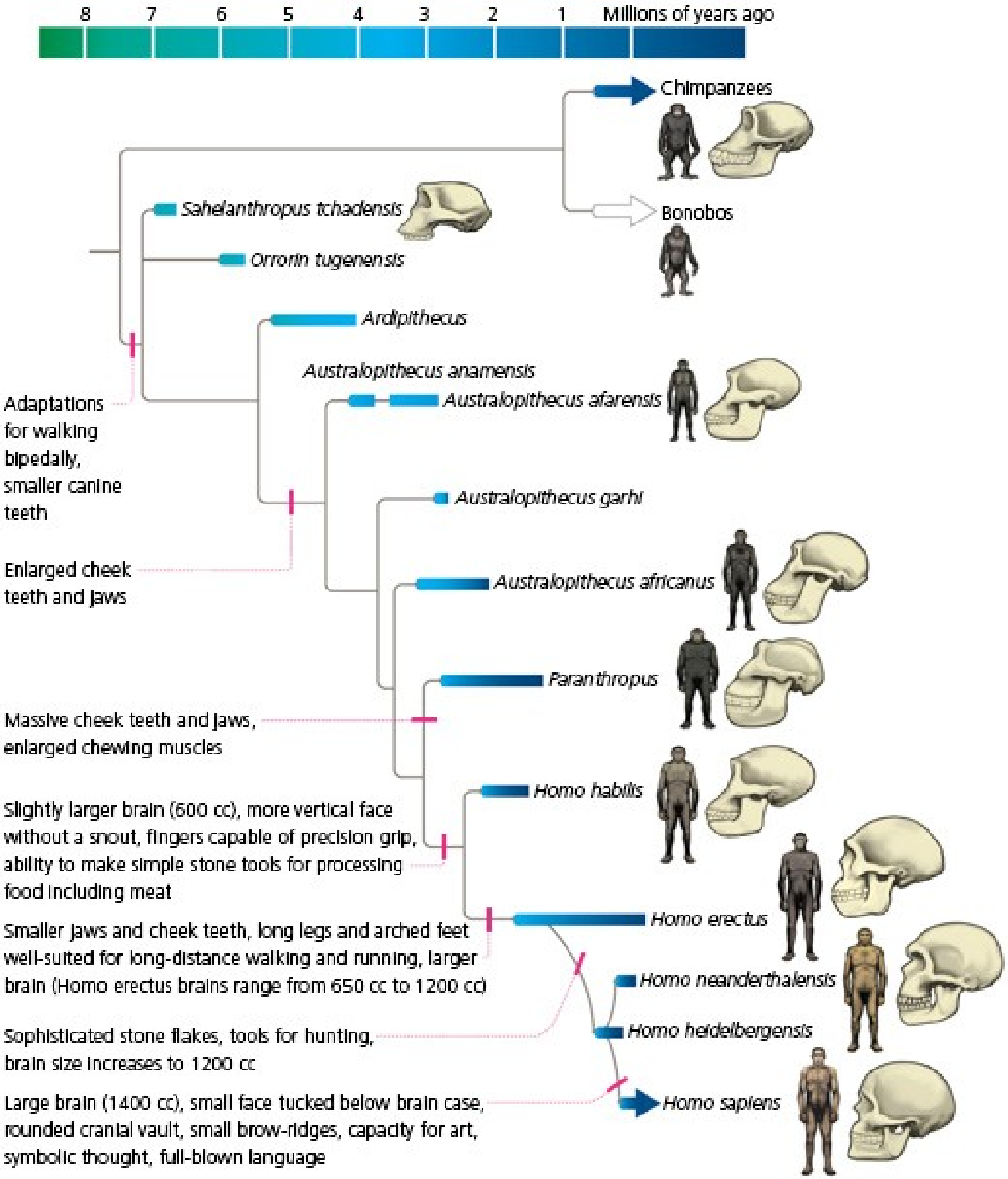

Chimpanzee
Lucy
Australopithecus afarensis
Modern human

Australopithecines – widespread, at least six species, relatively small, facial structure and brain size similar to chimp

Homo – increased brain size, stone tools

- *Homo sapiens* 30,000 years ago
- Taller, lighter-weight, slightly smaller brain capacity (about 5.7 cups) than *H. neanderthalensis* (about 6 cups)
- **Out of Africa hypothesis** supported over multiregional hypothesis


Singe Anthropoïde
Australopithecus africanus
Homo habilis
Homo erectus
Homo sapiens neandertalensis
Homo sapiens sapiens
capacité crânienne en cm^3
1500 cm^3
1000 cm^3
500 cm^3
Homo sapiens sapiens
Homo sapiens neandertalensis
Homo erectus
Homo habilis
Australopithecus africanus
Lukeino (Baringo)
Ancêtre du millénaire
Singe Anthropoïde
Primate
Préhominidés
Hominidés
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
-1,7
-0,7
millions d'années



Adaptations for walking bipedally, smaller canine teeth

Enlarged cheek teeth and jaws

Massive cheek teeth and jaws, enlarged chewing muscles

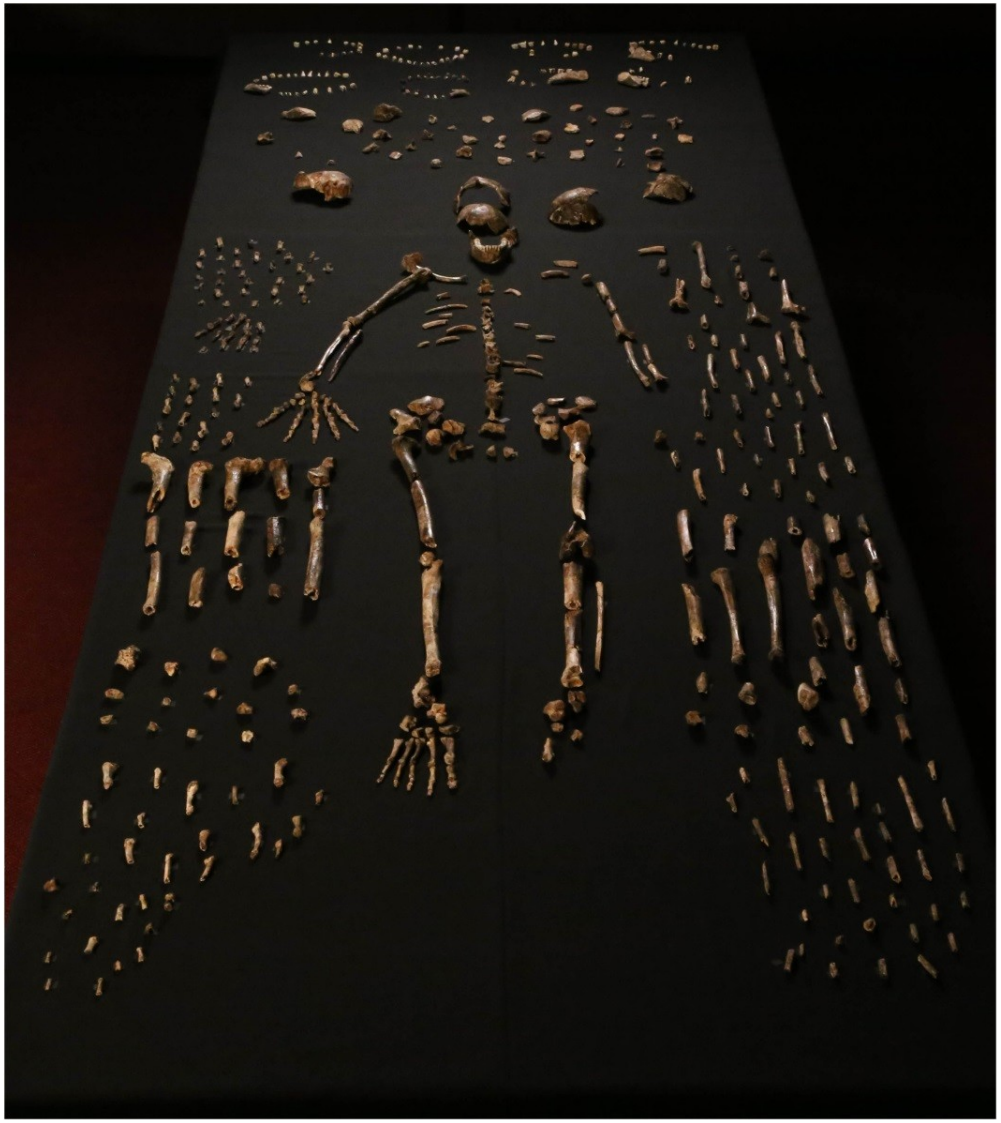
Slightly larger brain (600 cc), more vertical face without a snout, fingers capable of precision grip, ability to make simple stone tools for processing food including meat

Smaller jaws and cheek teeth, long legs and arched feet well-suited for long-distance walking and running, larger brain (Homo erectus brains range from 650 cc to 1200 cc)

Sophisticated stone flakes, tools for hunting, brain size increases to 1200 cc

Large brain (1400 cc), small face tucked below brain case, rounded cranial vault, small brow-ridges, capacity for art, symbolic thought, full-blown language

Homo naledi, a new species of the genus *Homo* from the Dinaledi Chamber, South Africa: Berger et al. eLife **2015**;4:e09560. DOI: 10.7554/eLife.09560



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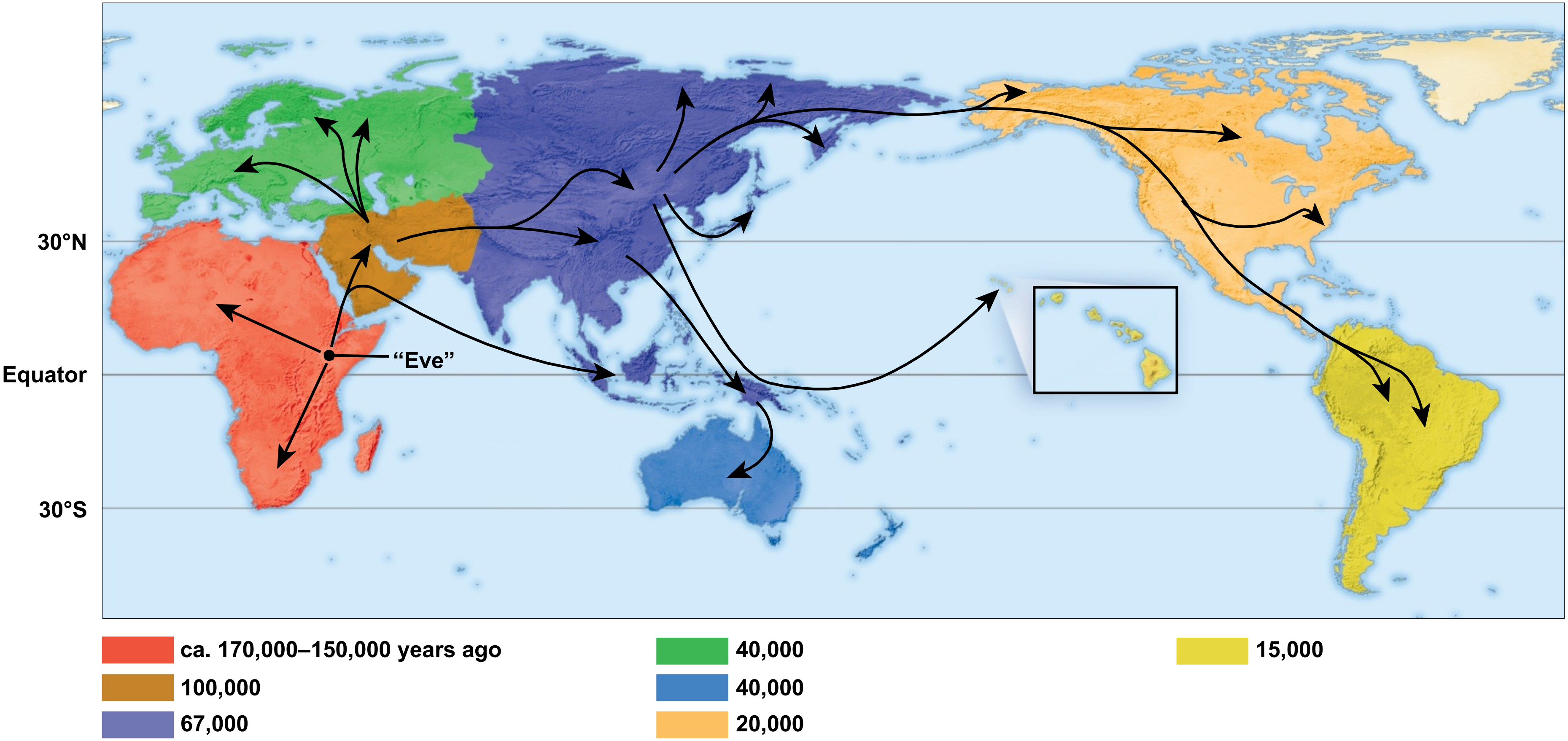
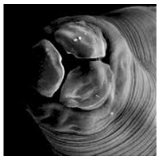


Study Skill: Compare and Contrast

Other study skills: Matching, Active Recall

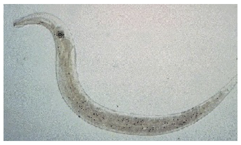
List of Nematodes: Matching Nematodes- After students have matched the nematodes I want them to talk about the similarities and differences they share.

Ascaris lumbricoides – can survive for long periods in soil and humans can get them from eating contaminated undercooked vegetables

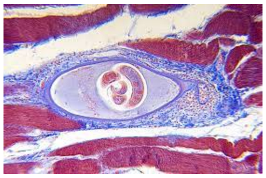


Hookworm – most common is the *Necator americanus*, and can cause anemia

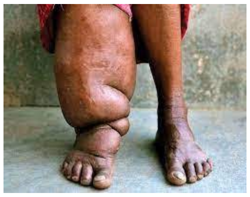
Pinworm – most common among children



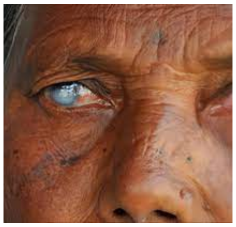
Trichinella – encyst into your muscles



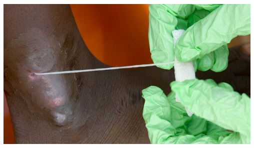
Wuchereria- causes elephantiasis



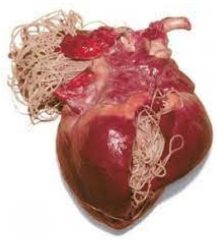
Onchocerciasis – disease also known as river blindness



Guinea Worm – causes Dracunculiasis



Dirofilaria immitis – Dog heartworm



Session: Fishing Game: After each question, I will make sure to try to ask "checking for understanding or CFU" questions specifically so that students continue to practice the study skill compare and contrast.

1. What is ecdysis? (To molt) CFU: How does this differ with lophotrochozoans?
2. Which phyla molt? (Tardigrades, **arthropods, nematodes**) CFU: Whats the difference between these phyla, aka what organisms do we find in these phyla?
3. What is cryptobiosis? (All processes stop to survive harsh conditions) CFU: Which animal does this?
4. What body cavity do nematodes have? (pseudocoelomate) CFU: What does it mean to pseudocoelomate and what is another example of an organism that has a pseudocoloem? (rotifers)
5. What symmetry do nematodes have? (bilateral) CFU: What is another organism that has bilateral symmetry?
6. What type of habitats can nematodes be found in? (All habitats from cold poles to warm tropics)

7. What covers and protects a nematode's body? (Collagen cuticle)
8. What muscles do they have: longitudinal, circular, or both? (longitudinal) CFU: What is an organism that had both longitudinal and circular muscles (annelids)
9. What does it mean for a nematode to have a hydrostatic skeleton? (Pushes muscles against fluids to move) CFU: What is another organism that has a hydrostatic skeleton? (earthworms)
10. Nematodes can be described as "eutely," what does that mean? (Have the same # of cells as adults, 959 cells to be exact)
11. Do nematodes have a complete or incomplete digestive tract? (complete) CFU: What is an example of another organism with a complete digestive tract? What about incomplete?
12. Which nematode has 3 lips? (*Ascaris,* strong pharynx as well) CFU: What about the hookworm?
13. Describe the life cycle of the *Ascaris* nematode. (Eat contaminated veggies, travel to the intestine, burrow through the intestinal wall, bloodstream or lymph vessels, lungs, and alveoli, cough up, and swallow again into the intestine). CFU:
14. These nematodes can burrow through your skin and into your blood (hookworm). CFU: What do hookworms have that allow them to burrow and how does this differ to *Ascaris*?
15. After hookworms have entered your bloodstream, what happens next? (Migrate to the lungs and are coughed up to be swallowed and mature in the intestine)
16. At what time do pinworms migrate to deposit eggs around the anal region? (At night, wait for the body temperature to cool and deposit them right outside)
17. How are pinworms passed along? (Scratching anal region and not washing hands, contaminating what is touched)
18. How can a person get Trinchinellosis? (Eating raw, undercooked meat)
19. Where can *Trichinella* encyst? (Muscles like the tongue, eyes, between ribs, heart, and brain)
20. *Wuchereria* requires a secondary host, what is it? (Arthropod, mosquito)
21. What is elephantiasis and what body parts does it affect? (Swelling of connective tissues, scrotum, legs, and arms)
22. What secondary host is river blindness carried by? (Black flies, arthropod)
23. What intermediate host does the guinea worm have? (transmitted through water, drinking copepod w/ larvae, arthropod)
24. How is dog heartworm transmitted to dogs, and even cats? Can they be cured? (mosquito, stop infection with pills).

Closing: Nematodes VS ? (Venn-Diagram)
The goal of this closing will be for students to compare & contrast Nematodes w/ another phylum that we have covered in class.

4/12

Urostyle frog practical.

Study Skill: Building Confidence

https://docs.google.com/presentation/d/1R6gQsCRRuL9392Iv7F0VZg_jwWcftEggjCOS3sGeDD0/edit?usp=sharing

Session: Place Your Bid
Students will use play money to place their bets on their confidence in answering/locking in an answer.

1. Which of the following phyla are protostomes?
   a. Nematoda
   b. Echinodermata
   c. Arthropoda
   d. Chordata
   e. Tardigrada
2. Match the following roundworms to their proper descriptions:

A.) *Ascaris, B.) Trichinella*, C.) Hookworms, D.) Pinworms, E.) Filarial worms, F.) *Guinea Worm*

___ encysts into muscles (B)
___ burrow through the skin (C)
___ lay eggs around the anus at night (D)
___ survive for long periods in the soil (A)
___ intermediate host is a copepod (F)
___ responsible for heartworm in dogs and elephantitis/river blindness in humans (E)

3. Which of the following answer choices appropriately describes the life cycle of a hookworm?
   a. Swallowed, intestine, burrow through intestinal wall, enter bloodstream/lymphatic system, lungs, coughed up and reswallowed, mature in small intestine
   b. Burrow through skin, enter bloodstream, lungs, coughed up and swallowed, mature in intestine
   c. Ingested, stomach acids break down cysts, larvae invade the bowel and mature, migrate to striated muscles to encyst
   d. None of the above
4. What features do animals in the subphylum Chelicerata share?
   a. Chelicera
   b. Pedipalps
   c. 3 pairs of walking legs
   d. No antennae

5. Are spiders more closely related to horseshoe crabs or cockroaches? (Horseshoe crabs)

6. What organ or structure do spiders use for oxygen uptake?
    a. Malpighian tubules
    b. Book gills
    c. Exoskeleton
    d. Pedipalps
7. What is spider silk made of and used for?
    a. Protein; webs, safety lines, wrapping eggs, dispersal of young
    b. Sugars; webs, safety lines, wrapping eggs, dispersal of young
    c. Lipids; webs, safety lines, wrapping eggs, dispersal of young
    d. Combination of sugars/proteins; webs, safety lines, wrapping eggs, dispersal of young
8. Which of the following describes a centipede?
    a. 2 pairs of legs per segment
    b. Produce hydrogen cyanide for defense
    c. 1st segment is modified to venom claws
    d. Herbivores
9. Do arthropods have an open or closed circulatory system? (open)

10. What 2 types of metamorphism do insects have? What is the difference? (Complete-holometabolous and incomplete-hemimetabolous)

11. What allows tardigrades to survive harsh conditions?
    a. Special bacteria
    b. Cryptobiosis
    c. Hides underground
    d. None of the above
12. What are biramous appendages? What subphylum of arthropods have this characteristic?
    a. Myriapoda
    b. Chelicerata
    c. Hexapoda
    d. Crustacea
13. How do insects perform gas exchange?
    a. Diffusion over the skin
    b. Tracheal tubes throughout the body with spiracles and pump abdomen
    c. Lungs
    d. Book gills

14. Which of the following has halteres and what is their purpose?
    a. Butterfly
    b. Bee
    c. Beetle
    d. Fly
15. What structure do sea urchins use to scrape algae?
    a. Madreporite
    b. Pedicellaria
    c. Aristotle's lantern
    d. Spines
16. What is the entrance to the water vascular system of a sea star?
    a. Tube feet
    b. Ampullae
    c. Pedicellaria
    d. Madreporite
17. Which of the following best describes the symmetry of an echinoderm from larvae to adults?
    a. Radial, pentaradial
    b. Bilateral, bilateral
    c. Bilateral, pentaradial
    d. Pentaradial, bilateral
18. Which of the following best describes the features of a starfish? Select all that apply:
    a. Eyespot at tip of each arm
    b. 2 stomachs
    c. Regenerate arms
    d. Madreporite on oral side and mouth on aboral side
    e. Ossicles fused in the endoskeleton
19. The tentacles of a sea cucumber are modified for.. (feeding)

20. What chordate characteristics do tunicates retain?
    a. Notochord
    b. Dorsal hollow nerve cord
    c. Endostyle
    d. Pharyngeal gill slits
    e. Post-anal tail
21. What chordate characteristics do lancelets retain?
    a. Notochord
    b. Dorsal hollow nerve cord
    c. Endostyle
    d. Pharyngeal gill slits

    e. Post-anal tail

22. Define the following terms: oviparous, ovoviviparous, viviparous

23. How many chambers are found in the hearts of fishes, amphibians, reptiles, and chordates (respectively)?
    a. 2,3,3,4
    b. 2,3,3 (except for birds), 4
    c. 2,3,3 (except for crocodiles), 4
    d. 2,3,3,(except for bird and crocodiles)4
24. Which of the following lacks a vertebrae?
    a. Lamprey
    b. Hagfish
    c. Bony fishes
    d. None of the above
25. Which are the cartilaginous fishes?
    a. Hagfish and lampreys
    b. Tunicates and lancelets
    c. Sharks and rays
    d. Bony fishes
26. What makes sharks such good predators? What is unique about their scales?

27. Which group led to the tetrapods?
    a. Amphibians
    b. Lobe-finned fish
    c. Hagfishes
    d. Ray-finned fish
28. What gives sharks their buoyancy vs bony fishes, respectively?
    a. Oily liver, swim bladder
    b. Swim bladder, oily liver
    c. Swim bladders are found in both
    d. Both have swim bladders and oily livers
29. What is the operculum?
    a. Found in sharks, bony flap of skin to aid movement of water over gills
    b. Found in ray-finned fishes, bony flap of skin to aid movement of water over gills
    c. Found in ray-finned and lobe-finned fishes, bony flap of skin to aid movement of water over gills
    d. Found in sea stars and other echinoderms, bony flap of skin to aid movement of water over gills
30. Which group of dinosaurs led to the bird lineage?
    a. Saurischia- Lizard-hipped dinosaurs

    b. Ornithischia- bird-hipped dinosaurs

31. The ancestor of modern mammals is the
    a. *Archaeopteryx*
    b. Cynodont
    c. *Tiktaalik*
    d. Trilobites
32. Monotremes are..
    a. Egg laying mammals
    b. Pouched mammals
    c. Placental mammals
    d. None of the above
33. What are some adaptations for flight in birds?

34. Why is *Tiktaalik* significant?

35. Why are amphibians tied to water while reptiles and mammals are not?

36. What are the components of the amniotic egg?

37. What are the benefits and harmful effects of having insects?

38. What are some mammalian characteristics?

39. What are the 5 chordate characteristics and their functions?

40. What issues had to be addressed when transitioning from water to land?